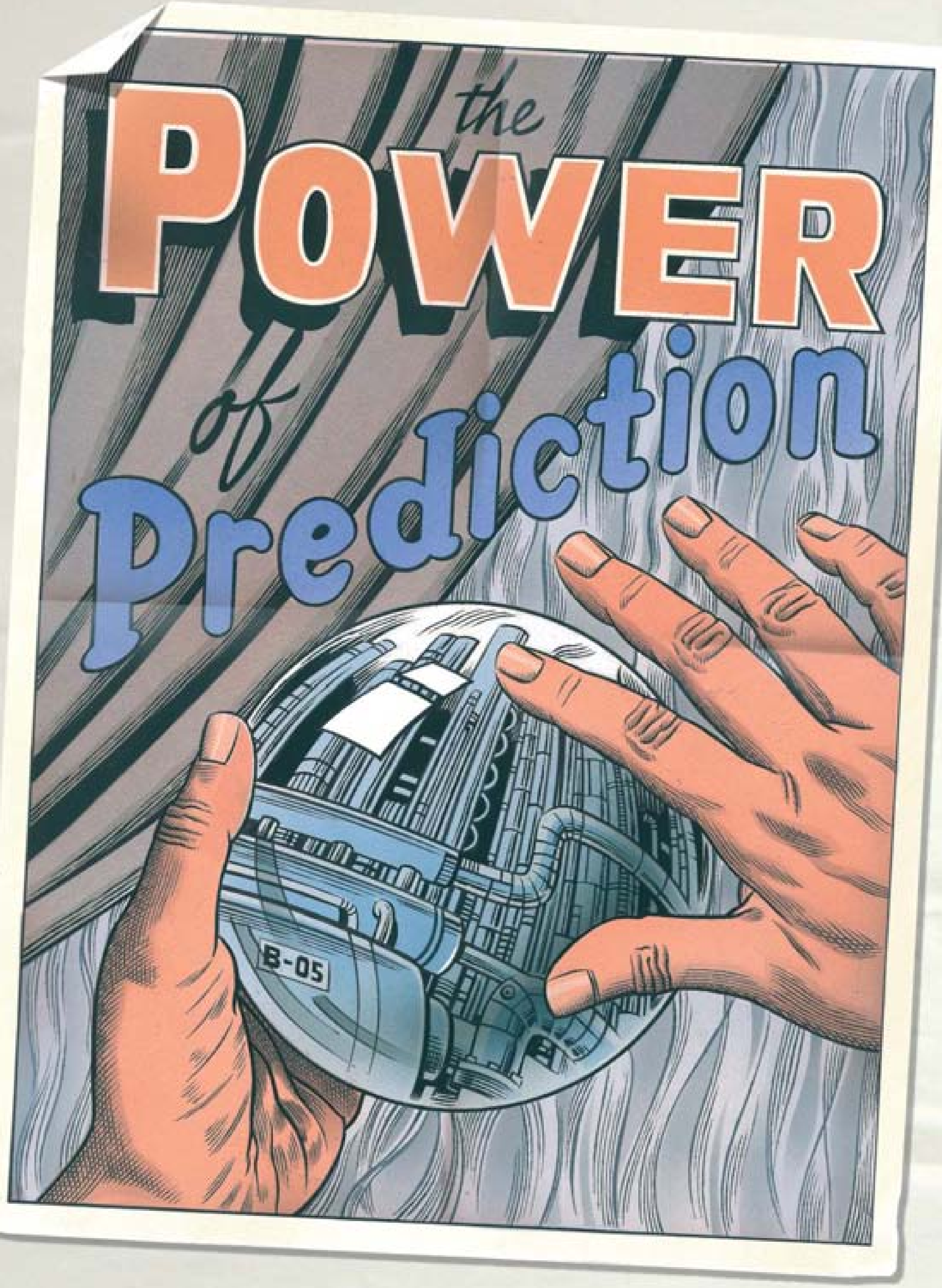
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New software and diagnostic techniques are helping BP's engineers to spot potential problems before they occur in the company's giant acetyls chemicals complex in the UK. And being forewarned is forearmed, as *Michelle Brown* learns

Foresight is a marvellous thing. On a busy chemicals complex, knowing what potential operating problems might be brewing can make the difference between taking timely action to keep things running smoothly, or facing an expensive, unplanned halt in production. At its UK petrochemicals site in Hull, BP's acetyls business unit is using cutting edge techniques to monitor equipment and processes in ways that allow BP's engineers to nip those potential problems in the bud.

'Early detection of such problems will yield estimated savings approaching £2 million a year across the site,' says process automation team leader Tim Law, 'and it will help BP to extend the time between planned maintenance shutdowns from two to four years on our largest acetic acid plant.'

The new approach being applied in Hull is referred to as abnormal situation management (ASM), embracing a variety of ingenious diagnostic tools that engineers are using to spot seemingly insignificant early symptoms that could lead to trouble in a few hours or days. 'A couple of hours' warning can make all the difference,' says Zaid Rawi, BP's lead engineer on the ASM project and a member of the process automation team.

ASM is part of a wider initiative at Hull called PUMA – producing the ultimate manufacturing asset – a programme of improvements launched in 1999. PUMA is one of three pilot initiatives forming part of Manufacturing Vision, the focus within BP's chemicals business for the BP-wide Operations Excellence efficiency drive, launched by group chief executive Lord Browne.

'Before we began the pilots, we could not precisely predict the hard financial benefits of these technologies,' says Steve Hetherington, project manager for PUMA. 'Now BP can be much more confident of the financial justification for future projects because we've demonstrated that ASM technology does work and that it will reduce plant downtime.'

And reducing plant downtime at a complex as large as Hull has obvious economic benefits. The Hull chemicals complex, located at Saltend on the River Humber estuary, has a manufacturing capacity of over 1.5 million tonnes of chemicals a year, making it the largest producer of acetic acid and associated products in Europe and the second largest acetyls complex in the world. The plant boasts six production units making a variety of important feedstock chemicals: acetic acid, used in plastics, packaging, paints, food preservatives, pharmaceuticals and photography; acetic anhydride, for the manufacture of bleach, pharmaceuticals and herbicides; ethyl acetate, for pharmaceuticals, paints, printing inks and photography; vinyl acetate monomer, used in paints and adhesives; acetone, a key ingredient in coatings, polyvinylchloride (PVC), printing inks and pesticides; and mixed acids, for everything from biocides to perfume.

The challenge faced in chemicals manufacturing is being data rich and information poor

Chemical plants such as Hull went through a transition in the early 1990s with the advent of intelligent, distributed control systems, hailed to be ushering in a new age when plant operators throughout the process industries would have all the information they needed at their fingertips to optimise production. Today's reality is rather different, says Rawi. 'The challenge we face in manufacturing is that we're data rich and information poor. Distributed control generates readings from instruments in every corner of the plant. Too many inputs, especially in the forms of alerts and alarms, can leave operators trying to deal with everything at once. Logging all of this in large data libraries is of little practical benefit if no-one has time to look at it.'

With ASM, BP is turning the data into something more useful. Applied correctly, ASM can give an early warning system of what is happening on the plant, a proactive system rather than simply a reactive one.

Equipment health

The ASM strategy takes a two-pronged approach: equipment health management (EHM), which uses early symptoms to diagnose a physical fault – similar to knowing the 'health' of an equipment item – and overview plots, which help operators see the big operational picture of the plant at a glance.

For the work on equipment health management, BP teamed up with Honeywell as a main development partner, although several software companies became involved at subsequent stages. 'This is cutting edge stuff,' says Rawi. 'It wasn't just a question of buying in software. BP has had a lot of input, because we are really pushing the boundaries of the industry with what we're doing at Hull.'

The prime candidates for EHM are the workhorses of any process plant, such as pumps, compressors and heat exchangers. The diagnostic system is programmed to recognise the symptoms that indicate an item of equipment is going to cause problems. For example, if a compressor's bearings are about to fail the first sign may be contaminated lubricant. If the bearing >>

BP's chemicals complex at Hull is the largest producer of acetic acid and associated products in Europe

>> temperature then starts to rise and the assembly starts to vibrate, the system recognises that failure is imminent.

The EHM system can also be programmed with equations governing the normal behaviour of equipment. It 'understands' that if a pump moves away from its normal operating curve its impeller may be worn, or if a heat exchanger becomes less efficient it is probably because of fouling inside the heat exchanger tubes. Some pieces of equipment are 'standard', for example most pumps, so engineers can devise a generic template of parameters that define normal behaviour. Other equipment, for instance larger compressors, must be analysed individually.

An added challenge in setting up EHM was making sure that the system had all the readings it needed – engineers wanted to avoid investing in expensive new instruments, but the type of existing instrumentation was not originally installed with EHM in mind. For example, determining a pump operating curve depends on knowing the pressure at the inlet, but there was not always a sensor installed at that point. Instead, the system is able to generate an inlet pressure measurement from an actual reading taken from the fluid level in an upstream tank, calculating the pump inlet pressure from hydrostatic head.

In other cases, the behaviour of equipment can be so complex that engineers can't really define it using equations. The ways in which a compressor vibrates in response to different operating conditions is a good example. In this case a 'black box' model is applied, which 'learns' how the equipment should behave under different conditions by looking at how it has behaved in the past. 'The idea is to be able to predict what the vibration ought to be from other variables,' says Rawi. 'If the result is different, you may have a problem.'

Not all the targets in the EHM system are large equipment items. The multitude of electronic controllers and valves across the chemicals complex, which are continuously making small adjustments to automatically control pressures, flows and temperatures, have also been pulled into EHM, relieving some of the burden on control engineers who may be individually responsible for checking hundreds of control loops around the plant.

Abnormal situation management is helping BP reduce plant downtime

Typical problems associated with these loops may be physical, for example, a valve may be sticking, or perhaps a controller may be tuned to the wrong settings so that it overshoots its target. Such events can set up oscillations throughout the process and can be tricky to eliminate, as it is sometimes difficult to pinpoint the root cause within a large process.

To tackle this situation – which occurs industry-wide – BP's engineers have installed a monitoring package from software company ExperTune called PlantTriage that monitors more than 1650 control loops around the site. PlantTriage examines an individual control loop by monitoring standard parameters such as its set point, or operating target, and uses pattern recognition to spot the characteristic responses of a sticking valve or a badly tuned loop. It also uses a mathematical tool to analyse the frequency of oscillations, seeking to match up apparently separate oscillations in different control loops – either of which may be the root cause of the other's odd behaviour.

Having the plant 'wired up' to monitor equipment responses and unusual behaviours is a vital step towards one of EHM's key goals – reducing the number of alerts and alarms going off in the control room. The system achieves this by serving as a repository for early warning alerts – 'traffic lights' flag up equipment that may be cause for concern, and which may need attention of engineers at some stage, but which do not immediately demand the active response of an operator in the control room. But there is no risk of compromising plant safety – any critical and immediate failures are alarmed in the control room to the operators as usual. EHM also helps to prioritise maintenance work, and can generate automatic work orders to accompany this.

A less obvious benefit of EHM is its ability to translate the trend data it collects from equipment into 'operating envelopes' to optimise processes in ways that would have been impossible before.

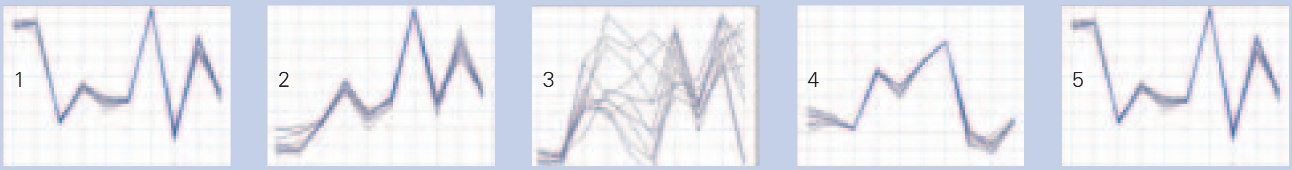
'Insidious problems such as accelerated corrosion or fouling previously had only limited early warning systems,' explains BP's James Chilton, group engineer at Hull. 'In contrast, the new system at Hull can alert staff that corrosion or fouling is occurring due to movement of the plant to an undesirable operating regime within its normal boundaries. We've found we can operate the process in a "sweet spot" that prevents these problems. It's similar to driving your car gently to extend the time between maintenance services.'

Seeing the big picture

The second aspect of ASM is enabling operators to see the 'big picture', rather than overloading them with too much detailed information.

Pattern recognition

The parallel co-ordinates monitoring technique checks on a range of plant parameters, each plotted on a vertical scale, to produce a profile for 'normal' operation. In this example, a carbon dioxide removal scrubber is being monitored with 10 parameters – for example, pressures, temperature levels, and flow rates. The points are joined up to form a profile which is refreshed every minute, and shown in periods of 10 minutes of plant operation. The plant starts off operating in a stable way (see 1 below), but as one parameter begins to change (dropping temperature), the profile begins to change (2). An oscillation is set up in other plant parameters as the scrubber begins to experience liquid foaming (3), clearly seen in the profile. The scrubber is returned to a stable state by decreasing the flow rate through it, giving a different operating profile (4). The original problem is resolved and the plant returns to normal operation (5).



'With modern digital displays the control room operator has lost the option of glancing across a panel of gauges to see the state of his plant by pattern recognition,' says Rawi. 'We have developed a way with ASM of taking advantage of the brain's ability to rapidly recognise patterns and deviations from normal situations.'

The most powerful of the methods that underlie this is multivariate statistical analysis, which compresses many variables from the plant into fewer compound variables that can be plotted on a two- or three-dimensional chart.

Essentially, the technique results in a 'bull's-eye' pattern, with the overall plant operating condition shown as a point that should fall close to the centre. If it doesn't, the system can be interrogated to see which of the original variables is most responsible for knocking the process off-centre. The BP engineers worked closely with researchers at the University of Newcastle to develop the models.

The bull's-eye technique has proved to work well once it is set up for a given operating regime at the plant, and work is in progress to make it effective when the plant is switched between alternative modes of operation. Meanwhile, other techniques for presenting the big picture have also been deployed.

'Some of the other techniques we use may be less powerful than multivariate statistical analysis, but they are generally easier to deploy and visualise,' says Rob Sutton, human-machine interface engineer.

Inside the new control centre at Hull, where BP's equipment health management system reports potential problems before they occur

Two such techniques are parallel co-ordinates and radar plots, each of which seeks to show multiple parameters in a graphical way to make any deviations easier to spot. The parallel co-ordinates approach takes a 'snapshot' of the different variables at a given moment and plots them on a row of vertical axes (see diagram above). The resulting curve is then reported at given time intervals. If the successive plots fall in the same place each time, the process is stable, but if parameters start to shift they can be detected well before they reach their alarm limits. Radar plots place individual readings around a central point to form a 'blob', rather than a curve.

Observing a problem in this way still requires someone to be watching the plots, which led Martin Brown, a BP control engineer at Hull, to devise a method of getting the control system itself to do the watching. 'The system measures how much the current plot shape deviates from the learned norm and triggers an alert once the total deviation reaches a set limit,' he explains. 'The operator can then drill down for more information about what is causing this.'

The success at Hull is attracting wide-spread interest from other BP businesses that are keen to see what the new ASM techniques have to offer.

'Now that we have the experience of developing the cutting edge, future implementations are likely to yield profitable results more quickly,' Rawi points out. 'The software market in this area is hotting up, and as the technology develops, more of the initial set-up work will be carried out automatically. At Hull, we are already seeing clear benefits from having the foresight we've always wanted.' ■