A model of detection

Dr Sonny Llave, Dr Dale Erickson and Dr Michael Mai, Multiphase Solutions, Inc., USA, describe a field proven technique for the leak detection modelling of long distance multiphase subsea pipelines.

The ever increasing push to bring vital oil and gas commodity to consumers has seen the advent of the construction of very long subsea pipelines; covering distances unheard of until recent times. Today’s subsea pipelines routinely exceed the 500+ km mark, as long distance pipelines increasingly become the norm and the petroleum industry pushes the envelope in exploring and producing from deeper waters.

Examples of these modern marvels of pipelining technology include the West Natuna Transportation System (offshore Indonesia), Malampaya Export Pipeline (offshore the Philippines) and the Bayu-Undan-Darwin pipeline (currently under construction offshore Western Australia).

Although these examples are of dry gas pipelines, even recently built subsea multiphase pipelines are pushing the technology limits. Cases in point include the likes of the 370+ km Nam Con Son Pipeline (offshore Vietnam), which is currently the longest subsea multiphase pipeline in the world.

One thing is evident. The industry will keep pushing the ‘distance’ envelope as long as the economics play well in any particular development. However, along with this push in technology comes the challenge of the daily monitoring and maintenance of the operational integrity of these technological marvels. This task is difficult enough on land based pipelines where easier access is available. In a subsea environment, the difficulty grows exponentially. One of the issues is not having the capability of installing enough instrumentation on the pipeline to enable continuous monitoring of the health of the pipeline operations. Water depth and the availability of a suitable power source for instruments are typical issues to rear their heads when dealing in subsea conditions. Even relatively short subsea pipelines offer a considerable challenge.

The proven solution

Over the last decade, a significant number of advances in pipeline simulation and software systems technology have enabled the real time, online monitoring, control and optimisation of multiphase and single phase operations.

Multiphase (MSI) has been at the forefront of this activity, developing and implementing comprehensive pipeline and asset management systems that are particularly focused on handling these demanding conditions for subsea and, as well as for onshore applications. These are ‘fit for purpose’ software systems, based on the field proven Virtual Pipeline Manager™ or Virtual Asset Manager™ platform, and they have been applied to complex multiphase and single phase (gas and liquid) pipeline networks to provide monitoring, control and optimisation functionalities.

In fact, a VPM based leak detection system is the only online model based package to rigorously model true multiphase operations.

These leak detection systems utilise multiple methodologies to maximise leak
detection sensitivity and reduce detection time, while also minimising false or spurious alarms. These systems employ a model based technology (pressure transients and model compensated mass balance), coupled with a proprietary Bayesian statistical inference analysis and a high speed, hybrid, comprehensive, dynamic pattern matching ‘fingerprint’ technology, designed to provide accelerated detection times and improved sensitivity.

These systems’ dynamic pattern recognition/fingerprint technology continuously examine thousands of site specific system pattern parameters to determine the true fingerprint of a leak on a given pipeline segment, with automatic adjustment for longer term variations in system bias and noise. Each VPM based leak detection system is designed such that from ‘day one’ of onsite installation, each package has a built in ‘knowledge’ of possible leak response combinations for the whole pipeline infrastructure, even the long distance, sparsely instrumented subsea pipelines.

In addition, the leak detection technology incorporated into the VPM is only a small component of the wealth of functionalities that can be delivered. These systems are designed ‘fit for purpose’, providing mission critical pipeline and asset management functions, including closed loop control of operations and real time optimisation.

**Technology in action**

The claims of the Virtual Pipeline Manager’s built in technological advances are meaningful only when actual field performance is available to back them. The proof is in the pudding.

In mid November 2003, a leak developed on one of these vital 500+ km inter-country subsea pipeline networks. This particular network is one of the largest international natural gas supply and delivery system’s in the Asia Pacific, inclusive of a 20+ in. subsea pipeline network, fed from three production platforms and operated by the individual production sharing contract (PSC) operators.

The leak event resulted in the temporary curtailment of delivery to industrial clients while repairs were made. True to the nature of ‘supply and demand’, the incident also caused a temporary spike in regional spot market gas prices.

With over 650 km to cover from the farthest supply platform, this offshore gas network is especially challenging from a leak detection application standpoint. The compliment of instrumentation on this massive infrastructure (e.g. Ps, Ts, Qs etc.) is only available at the production platforms and onshore receiving facilities.

The sheer ‘spatial’ relationship of such input signals, coupled with the significant volume of the pipeline’s linepack, makes this network extremely difficult to monitor accurately for leaks. In fact, under such operating constraints, other less sophisticated leak detection technologies would be rendered ineffective, particularly given that the subsea environment negates the option of installing any intermediate instrumentation points along the length of the network.

Instrumental in the rapid annunciation of the leak event and accurate determination of the leak location was the VPM system. This model based leak detection and location technology is part of a real time online advanced gas pipeline management system. This VPM system has been operational on this network since its first gas operations in late 2000.

This particular VPM package was designed ‘fit for purpose’ to provide mission critical gas management functions to assist the gas production controllers...
in handling the daily operations, including:
- Real time, online pipeline management and production control.
- Monitoring customer delivery and shortfall.
- Gas composition and quality tracking.
- Production blending management.
- Pipeline condition ‘look ahead’ forecasting, up to seven days from the current state.
- ‘What if?’ analysis forecasting and planning, up to seven days from current state or user defined scenarios.
- FDG™ based operator trainer system.
- Auto-recommendations of optimised operations tied to client nominations.
- PSC production substitution and balancing.

- Pipeline dew point monitoring and control.
- Onshore Receiving Facility heater conditioning set-point and closed loop control.
- Rigorous condensate dropout tracking and prediction, in the event of offshore platform processing disruptions.
- Interface with gas accounting system.
- Interface with Fisher Rosemount Delta V System via OPC.

Not only did the VPM system declare that a leak was in progress. It also accurately declared the leak’s location. The location grid declared by the VPM system was instrumental in pinpointing and narrowing down the helicopter search area. The VPM’s leak location accuracy was greatly accelerated in the visual detection process and the subsequent effort to repair and put back this vital network in full operations.

Clearly, early detection and accurate location played a pivotal role in ensuring safety and reducing environmental impact, at the same time minimising the downtime while repairs ensued. In the absence of such vital information, any pipeline operator would have to resort to flying over a vast area of open waters in search of the leak.

The VPM system declared the presence of the leak within a short period of time, based on interpretation of the minute deviations in the metered conditions, coupled with the built in fingerprint technology, even at such extreme instrumentation spacing. Emergency management procedures were then employed to assess and address the incident accordingly.

As the leak was detected much later in the day, the surface location of the leak (e.g., ensuing gas bubbles) was only visually detected by daybreak the following morning by the helicopter search team. The VPM system helped to narrow the helicopter search window to within a 5 km radius of the system declared location of the leak.

A key point to consider is that the actual location of the pipeline leak (as compared with the VPM predicted location) was even closer (i.e., within one kilometre of the actual leak location). The exact location of the leak was further verified when the ROV inspected the leaking pipeline section at the bottom of the ocean.

In the case of this network, being one of the longest and sparsely instrumented subsea pipelines in the world, the VPM system’s leak detection functional field performance was right on target.