Pipeline Intrusion Detections System for Guangdong Natural Gas Pipeline

CASE STUDY

THE SCENARIO

The client, Guangdong Natural Gas Group (GDNGG), manages more than 3,100 km of natural gas pipelines. GDNGG were constructing an additional 145km section of Natural Gas pipeline for increased supply to an urban area. The pipeline length for this section had 4 compressor stations along the length and 7 RTU valve rooms. The pipeline was buried in a trench to a depth of 1.5m, with a fiber optic telecommunications cable buried in the same trench.

The area around the pipeline was a heavy traffic construction zone, and the client was concerned that other unapproved construction activities by third-party companies may risk damage to the pipeline. Due to this, the company commissioned a Fiber Optic Pipeline Intrusion Detection System.

CLIENT REQUIREMENTS

The client required that any digging and excavation activity within the vicinity of the pipeline was detected and reported to the regional monitoring centre, who would then dispatch pipeline patrol teams so that action could be taken before any damage to the pipeline occurred.

The specifications for the detection algorithms and the specific detection rate criteria are detailed below.

Criteria	Details
Measurement distance from pipeline	• Mechanical digging – 20m from pipeline • Manual digging – 5m from pipeline
Location accuracy	• All events to be determined within 50m of the event
Probability of detection	• For all mechanical excavation and compaction and manual digging events there must be 100% probability of detection (e.g. all events must be detected)
Event verification rate	• >90% • For all events measured by the PIDS system there must be a greater than 90% verification rate by the on-site patrol

Figure 1 - Client Specifications

WHAT DID WE DO?

Bandweaver supplied multiple Horizon Distributed Acoustic Sensing (DAS) systems, plus Bandweaver's Maxview integration software, to comprise the Pipeline Intrusion Detection System. These Horizon DAS units utilised one of the spare optical fiber cores within the existing telecoms fiber optic cable. These units were located at block valve stations along the pipeline route as detailed in the diagram below.

Two of the systems were configured in double ended configuration, and the third system in single ended mode.

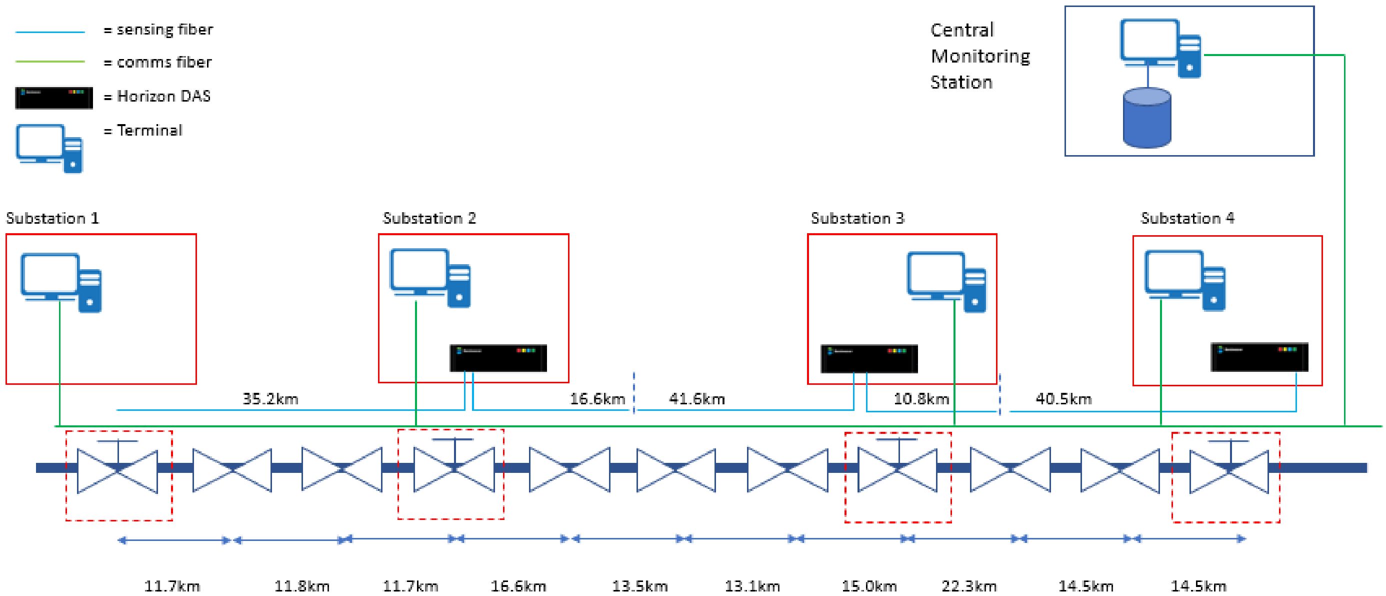

Figure 2- Overview of System Architecture

The project implementation and execution covered five distinct phases as detailed below:

Figure 3 - Project stages

System Installation

At the installation phase, the key tasks included reviewing the Optical Time Domain Reflectometry (OTDR) traces supplied by the telecoms integrator. These traces were then used to plan the system design and placement. Once the system locations are finalised, then the equipment is installed in each of the respective control rooms. Each system is then configured by the engineer with a preliminary configuration of the detection algorithms and maps within the software.

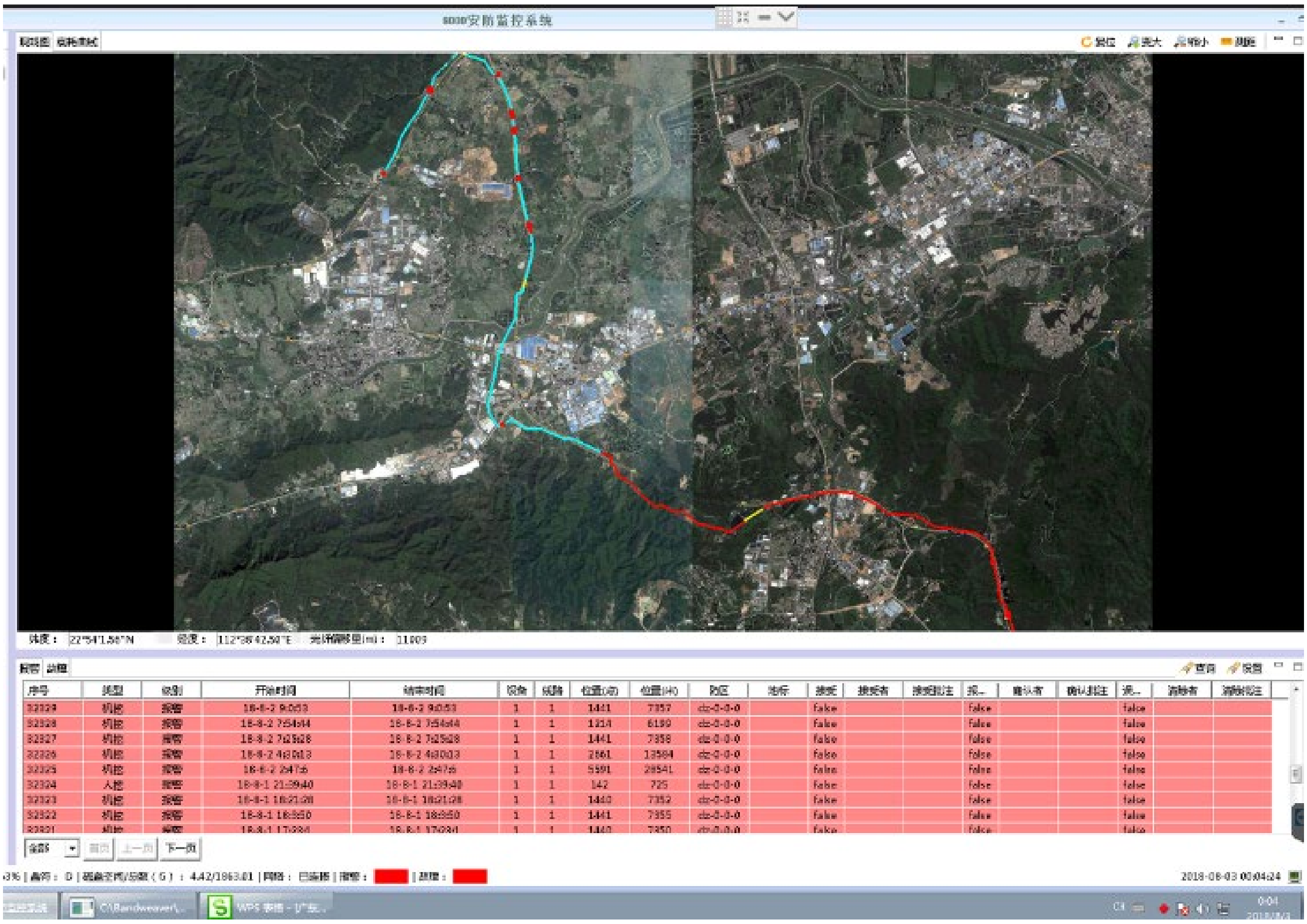

Figure 4 - Screenshot of map software

Site Survey and Calibration

The primary aims of the survey are as follows:

- Divide pipeline into environmental zones with similar values of:
  - Topography/ground hardness
  - Environmental conditions (e.g. water saturation, amount of traffic)
  - Measurement requirements
- Correlate fiber optic sensing cable distances with pipeline distances
- Obtain acoustic sensitivity pipeline sensitivity profile along pipeline

Figure 5 - Photo of on-site personnel

Data Acquisition and System Tuning

During the data acquisition and system tuning phase, initial sets of data were acquired. By then correlating the acoustic activity with the survey data, the monitoring zones were created. Based on the acoustic sensitivity, the detection algorithms for each zone were configured. Then, over a period, data was acquired to monitor the acoustic p*atterns of life*. Based on the data obtained, the algorithms are then adjusted accordingly to match the sensitivity and activity of the general environment.

System Commissioning

In order for the customer to sign off on accepting the PIDS system, a number of real life tests were carried out throughout the data acquisition and tuning phase. Below is a sample of some of the testing and results, which will give an idea of the process that was undertaken. The tests were typically done with a gap of 1-2 weeks in between each test.

No	Details of Test	Results	Follow up action
1	• 8 x manual dig tests • 1 x mechanical excavation test	• Successful on all 8 x manual digs • Mechanical failed to alarm within 5 minutes	• Used data replay function to retune algorithm to effectively alarm for mechanical
2	• 5 x manual dig tests	• 3 successful alarms • In 2 cases the PIDS system did not alarm	• In one case the cable was buried deeper and so the algorithm was tuned to adjust • In 2nd case the DAS detected a high optical event loss in the fiber optic. The owner was requested to repair the fiber optic
3	• 8 x manual dig tests	• 7 successful alarms • In 1 case the system did not alarm	• The DAS detected a high optical event loss in the fiber optic. The owner was requested to repair the fiber optic
4	• 5 x mechanical tests	• 4 successful alarms • In 1 case the system did not alarm	• The DAS detected a high optical event loss in the fiber optic. The owner was requested to repair the fiber optic

As can be seen from the results above, it is equally important to take care of the fiber condition and installation, as any damage to the sensing fiber (or high loss splices) can result in a degradation in the detection ability.

For the mechanical digging, the specification of the system was to detect mechanical excavation within 20m; however, the system performed far in excess of this requirement and could detect mechanical excavation between 30m to 70m from the pipeline. Manual digging also exceeded the 5m target and could detect manual digging at distances up to 10m from the pipeline. The system was successfully commissioned and put into active operation.

System Operation Phase

As the pipeline crosses a number of areas with extensive constructive activity, there were a significant number of detection events. During the first two months of operation, there were 96 detection events. In each case, a patrol team was dispatched to investigate the event. Below is a summary table of the events.

Zone ID	Number of Alarms	Identified Construction Events	No Construction Found
1	11	11	
2	12	12	
3	14	13	1
4	11	11	
5	48	40	8
Total	**96**	**87**	**9**
Event verification rate = 90.67%			

In 87 of the 96 cases, the patrol teams found unauthorised construction activity. As you can see, the event verification rate is above the target of 90%.

Of the 87 verified events, there were a number of different scenarios. But on multiple times, there were cases where mechanical excavation equipment was close to or even above the pipeline.

In one specific case, there was mechanical excavation activity directly above the pipeline. The excavator dug to a depth of 0.3m and damaged one of the control cables above the pipeline. The Horizon DAS alarmed and the patrol was deployed to the site before the machinery proceeded to the level of the pipeline (at a depth of 1.5m) and catastrophic damage was narrowly avoided.

Photo of excavator near pipeline

Photo of damage directly above pipeline

Figure 6 - Photos taken by patrol on site post alarm

BENEFITS TO THE CLIENT

The PIDS system based on Horizon DAS provides coverage of the entire pipeline, at all points along the length. Because the Horizon DAS has 2 channel capability, it is able to measure up to 100km for each system (50km in either direction). This long range capability gives a very cost effective system, with a high return on investment. The systems are integrated using Bandweaver's MaxView software, which gives the customer a user-friendly way to manage a complex system, and which seamlessly integrates into existing control systems.

Within the first 2 months of operation, the PIDS system based on Horizon DAS technology has already proved its worth to the customer, with multiple events detected and consequently avoided. For certain, some of these could have been catastrophic in nature, and with the average cost of a pipeline incident costing $345,000[1] , the Horizon DAS based system has already potentially saved millions of dollars. When you consider the additional reputational and litigation risk for this type of incident, then it is clear that an intelligent pipeline monitoring system is critical and should be included in all proactive asset protection strategies.

[1] Source: US Pipeline and Hazardous Material Safety Administration