



mPower – Pipeline Leak Detection

Introduction

Yokogawa's Exaquantum and mPower are together providing pipeline leak detection capabilities at a customer's tar sands installation.

The customer operates a facility for extracting oil from tar sands. The two main centres of the facility are located about ten kilometres apart and are connected by four oil-carrying pipelines. These pipelines require monitoring for possible leakage but, because they are relatively short and are only conveying liquids (and not gases) fully rigorous monitoring employing sensors located at intervals along the pipeline and calculations based on fluid dynamics are not essential. Consequently, commercially available leak detection systems were judged by the customer to be unnecessarily expensive and complex, so a simpler solution was sought.

The simplest possible system, based purely on comparison of measured volumes entering and leaving the lines, would not be able to produce sufficiently sensitive leakage alarms because of flow variations caused by temperature and pressure changes within the lines.

Analysis carried out by Yokogawa Marex demonstrated that, if contraction of the oil caused by cooling while passing through the line, together with expansion of the oil caused by pressure drop across the line were taken into account, leakage alarms with a sensitivity fully acceptable to the regulatory authorities could be produced.

An existing Exaquantum data historian system was augmented by the addition of mPower functionality so as to provide the required leak detection capability in an extremely cost effective manner. The additional functionality was incorporated into the same physical hardware, so that no additional hardware was required. In this instance all, annunciation and inspection of leakage alarms by the operators is carried out via the existing Yokogawa DCS system.

Exaquantum is Yokogawa's data historian. It accepts data from various data collection and control systems (e.g DCS, SCADA) and stores it in an efficient time-indexed database. A scripting language allows calculations to be performed on the input data, the results of which are also stored in the time-indexed database.

mPower is an extension to Exaquantum which, by adding information on the physical makeup and interconnections of a plant, enables additional information to be extracted from the individual data values stored within Exaquantum. This is done by configuring a topological model of the plant using component objects within the mPower software to represent processing units, tanks, interconnecting pipes, manifolds, long distance pipelines, jetties, etc.

Project Scope

The leak detection system was configured to cover:

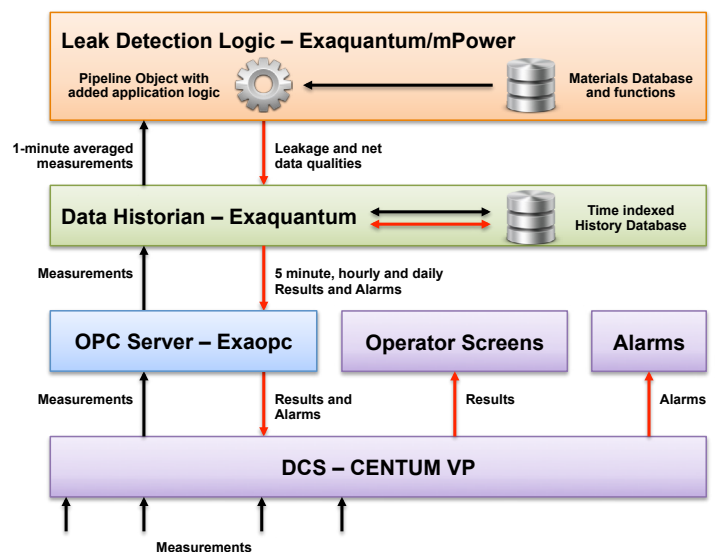
- Four oil pipelines running between sites
- Two oil pipelines running within one site, one of which was a fork off from one of the longer pipelines
- Two separate water pipeline networks which collect ground water from multiple wells into storage tanks

For each pipeline or pipeline network, leakage alarms are produced over three different time periods - five minutes, one hour and one day. The shorter period calculations can raise alarms more quickly but, allowing for measurement accuracies, are necessarily less sensitive. Thus larger leaks can be detected quickly, while smaller leaks can also be detected, but only after a longer time period has passed. This behaviour is adjustable by configuring the percentage of lost material in any time period which is taken to indicate that a leak is present. Longer periods use smaller percentages.

Temperature and pressure compensation is applied to the oil pipelines, but only simple volume balances to the water networks since their temperature is virtually constant throughout and pressure effects are negligible.

System Architecture and Display

The complete leak detection system is based upon a layered architecture as shown below:



Measurements of volumetric flow, temperature and pressures at both ends of the pipelines are gathered into the DCS and passed upwards to the Exaquantum historian via an OPC server. Within the Exaquantum layer circular buffers store the values for each measurement over the three calculation time periods involved.

Every minute, Exaquantum calculation tags pass these input data up to the mPower pipeline objects and receive back the amount of leakage for each line or network which has occurred during the minute, together with separate net quality indicators for volumetric flow, temperature and pressure. Each net quality is only set to "good" if the value of the associated data parameter was good at both the input and output ends of a line at the relevant times.

Exaquantum then compares the leakage amounts with the thresholds in percentage terms and raises alarms as required, taking due account of the quality indicators. The alarms themselves, and the supporting data, are passed down to the DCS for annunciation, display and inspection by the operators. A single DCS screen is used for this purpose, as shown below:

Pipeline	Alarm	Leakage Amount	Threshold	Alarm Status	Volumetric Flow Rate Quality	Temperature Quality	Pressure Quality	Determination
Pipe A	5 Minute	4.76 %	5.00 %	ALARM	ALARM	ALARM	ALARM	This minimum number of good values needed to achieve an initial net good quality
	1 Hour	4.76 %	3.00 %	ALARM	ALARM	ALARM	ALARM	
	24 Hour	4.76 %	2.00 %	ALARM	ALARM	ALARM	ALARM	
Pipe B	5 Minute	5.88 %	5.00 %	ALARM	ALARM	ALARM	ALARM	5 Minute 5
	1 Hour	5.88 %	3.00 %	ALARM	ALARM	ALARM	ALARM	
	24 Hour	5.88 %	2.00 %	ALARM	ALARM	ALARM	ALARM	
Pipe C	5 Minute	5.88 %	5.00 %	ALARM	ALARM	ALARM	ALARM	1 Hour 60
	1 Hour	5.88 %	3.00 %	ALARM	ALARM	ALARM	ALARM	
	24 Hour	5.88 %	2.00 %	ALARM	ALARM	ALARM	ALARM	
Pipe D	5 Minute	587.87 %	5.00 %	ALARM	ALARM	ALARM	ALARM	24 Hour 24
	1 Hour	587.87 %	3.00 %	ALARM	ALARM	ALARM	ALARM	
	24 Hour	587.87 %	2.00 %	ALARM	ALARM	ALARM	ALARM	
Pipe E	5 Minute	30.00 %	5.00 %	ALARM	ALARM	ALARM	ALARM	Watchdog
	1 Hour	30.00 %	3.00 %	ALARM	ALARM	ALARM	ALARM	
	24 Hour	30.00 %	2.00 %	ALARM	ALARM	ALARM	ALARM	
Raw Water	5 Minute	0.00 %	5.00 %	OK	OK	OK	OK	T-ALARM
	1 Hour	0.00 %	3.00 %	OK	OK	OK	OK	
	24 Hour	0.00 %	2.00 %	OK	OK	OK	OK	
Sewage Water	5 Minute	0.00 %	5.00 %	OK	OK	OK	OK	
	1 Hour	0.00 %	3.00 %	OK	OK	OK	OK	
	24 Hour	0.00 %	2.00 %	OK	OK	OK	OK	

For each pipeline, data for three alarms (judged over different time periods) are shown. The left hand columns show the percentage leakage during the time interval, whether the alarm is raised or not, and the threshold used to make this judgement. The right hand columns show the qualities of the flow, temperature and pressure measurements, based on a specified minimum number of good quality 1-minute values present in their aggregations. The minimum numbers for each time period are presented at the right hand side of the screen.

Because the operators have access to the data values and qualities upon which the alarm statuses are based, they can make informed judgements on the need for action following an alarm, adding their own knowledge of current pipeline operations (e.g. start-ups, piggings or shutdowns) which might be relevant.

A watchdog indicator is also transmitted to the DCS so that the operator can be confident that the multiple layers which make up the alarm system are all operating properly. The watchdog indicator is present near the right hand side of the DCS screen shown above.

All the data involved is also stored in the long-term Exaquantum historical database where it is available to support alarm tuning and investigation activities.

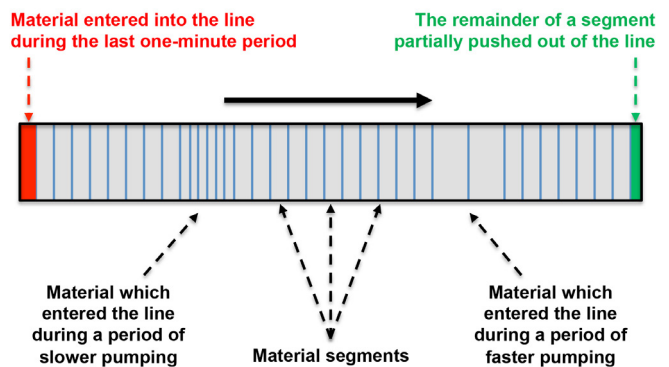
Enhancements and Implementation

The key to the operation of the leak detection system is the capability of an mPower pipeline object to subdivide the material contained within itself into segments and to track these segments as they pass through.

The mPower pipeline object is one of the components it uses to represent plant topology in software terms. Configured properties define the diameter and length of the line while logic within the object tracks material as it moves through from one end to the other. The material contained within the line can be split into separate segments according to need. Typically this is done if the material itself changes (e.g. two different oils following each other through a line).

When a known volume of material is added at the input, the pipeline object calculates the travel distance which this volume represents and moves all the segments inside itself down the line by that amount, thereby pushing material out of the far end.

In this application new segments are defined every minute when a known quantity of material, proportional to the measured flow rate, is added to the line. As a result, at any time, the content of the line is represented by a large number of small segments, as illustrated below:



An enhancement made to the segments for this project allows them to retain the temperature and pressure values and qualities which were current at the inlet end of the pipeline at the time when they entered. These are then used in conjunction with the equivalent data current at the outlet end when they exit to calculate shrinkage.

The pipeline objects within the mPower configuration have access to physical pipeline dimensions and also material identities and characteristics.

Within Exaquantum averaging of individual values over the various time periods used by the alarms is carried out by a set of standard calculation blocks, while a further small number of Exaquantum tags (approx. 50 per monitored pipeline) are required to complete the configuration. Local displays are provided to inspect, adjust and test the alarm logic at the Exaquantum level.

Input data values and alarm status and data outputs are transmitted to and from the DCS by normal OPC channels. Annunciation and display in the DCS is provided by normal DCS configuration, in this instance by making use of CAMS.