ILDS - AN INNOVATIVE APPROACH FOR LEAK DETECTION IN PIPELINES

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ABSTRACT

Leaks in pipelines have always been an issue and even a small leak has the potential to turn into a catastrophic event, if not detected and stopped in time. The recent regulations in many countries are also becoming more and more exigent regarding the environmental protection, so the Leak Detection Systems play an important role in any pipeline integrity program nowadays.

LDS are specially designed tools that help operators to quickly identify and react to a spill. These systems continuously monitor the pipeline operation and alarm deviations from normal condition that can be associated with a leak. There are several technologies in the market that calls for leaks detection, however, all of them have its own characteristics and limitations. A good set of features associated to a good performance in many different application scenarios is something not easy to achieve using just one methodology.

The Asel-Tech’s new ILDS (Integrated Leak Detection System) is based on two different Leak Detection methodologies and has been designed with focus to fulfill a complete set of desired characteristics with best possible performance. The innovative approach relies on the synergy between the two applied methodologies, the Negative Pressure Wave and the Mass Balance, that outstand complementary features and characteristics strategically combined in the ILDS. This combination grants to the ILDS unique features and improves the overall system performance gathering a rich set of features not found in any other leak detection pack currently available in the market.

1 - Introduction

Leaks in pipelines always imply in some kind of material losses and frequently also causes damages to the environmental and even to people, particularly when the transported fluids are dangerous to life and nature. Even a small leak has the potential to turn into a catastrophic event if not detected and stopped in time. The recent regulations in many countries are also becoming more and more exigent regarding the environmental protection, so the Leak Detection Systems play an important role in any pipeline integrity program nowadays.
LDS are specially designed tools that help operators to quickly identify and react to a spill. These systems continuously monitor the pipeline operation and alarm deviations from normal condition that can be associated with a leak. There are several technologies in the market that call for leaks detection, however all of them have its own characteristics and limitations. A good set of features associated to a good performance in the many different application scenarios is something not easy to achieve using just one methodology. Response time, sensitivity, reliability, accuracy and robustness are important performance parameters used to evaluate LDS. Applicability to a wide range of fluids and scenarios is also a highly desirable characteristic.

Asel-Tech’s new ILDS (Integrated Leak Detection System) has been designed with focus on all above mentioned characteristics and based on two different methodologies for detecting leaks: Negative Pressure Wave and Mass Balance. The concept is clearly recommended in API RP 1130. The innovative approach relies on the synergy between the two applied methodologies that have complementary features and characteristics strategically combined on the ILDS.

This combination allows unique features and improves the overall system performance by exchanging information and updating parameters in real time. Among the main benefits we could mention fast response time, accurate leak location, precise time stamp (GPS sync), leak rate estimation, spilled volume quantification, graphic trends, cross checking alarm validation and others, resulting in higher levels of sensitivity, robustness and reliability. This rich set of features is not found in any other leak detection pack currently available in the market.

2 - Leak Detection Methodologies

The two leak detection methodologies applied in the ILDS are the Acoustic or Sonic methodology, presented in the API 1130 as Negative Pressure Wave, and the Mass Balance. These two methodologies have been chosen due to its complementary features and characteristics, resulting in a perfect application synergy.

Following is a general description of each one.

2.1 - Negative Pressure Wave Methodology

The negative pressure wave methodology, as presented in API1130, also known as sonic or acoustic, works based on the identification of the hydraulic transients associated with the pipeline wall rupture on the leak onset. The generated transients propagate through the fluid in form of front waves, in both directions, at sound speed. The wave fronts are guided by the pipeline walls and can travel over very long distances before losing its energy. Special transducers installed at both ends of the monitored section measure the dynamic pressure converting it to an electrical signal that is read and analyzed by local processors named Field Processing Units (FPU).
The Field Processing Units are dedicated hardware running very sophisticated algorithms for proper signal processing and pattern recognition.

The wave front detection time at each sensor is precisely detected and registered and, since the propagation velocity is known, the leak location can be easily calculated based on the registered arrival times at the different FPUs. Time accuracy is assured by GPS interfaces, which keep all FPU clocks precisely synchronized.

Presence of back-ground noise and operational events, such as those originated by pump start/stop or valve opening/closing, require several different filtering techniques to properly extract and identify the leak signals. Effective filtering associated with multilayer detecting algorithms are the key to assure 100% of pipeline coverage with no any mute or silent zones. A few examples of applied filters are: correlation filters, band-pass, phase sequence, envelope follower, implemented both in hardware and software, plus innovative techniques based on artificial neural network (ANN) to improve the pattern recognition. This complex set of processing techniques assures the best performance of the acoustic module and grants to the ILDS its unique combination of features and characteristics.

2.2 - Mass Balance Methodology

This methodology permit to identify a leak based on deviations in the mass balance that result from the product release. The detection consists in the analysis of the difference between the outlet and inlet flow also considering the variations in the on-line calculated line-pack.

As inputs, the model uses measurements taken at both ends of the monitored section, (flow, temperature, pressure, density), and also the pipeline and fluid parameters and specifications configured in the system. Computational Fluid Dynamics (CFD) algorithms based on real-time flow modeling runs cyclically on the Central Monitoring Station, allowing on-line calculation of accurate flow profiles along the pipeline, including the transient regimens.

The outputs of CFD algorithms are fundamental for correcting the line pack calculation and also for real time parameters correction on the acoustic module, such as instant propagation velocity, attenuation, etc. The line pack variation can then be plotted against the in-out mass differences, producing characteristic curves that represent the behavior of the pipeline flow, making possible trend analyses and action even before a leak alarm is issued.

In the opposite way, when an alarm is issued, the precise time stamp from the acoustic module is used for starting the leak quantification.
3 - System Architecture

The ILDS architecture and its main components are shown in the figure 01, below.

Figure 01: Overall System architecture - ILDS

The Negative Pressure Wave methodology comprises Acoustic Sensors (FSS), Field Processing Units (FPU) and a Central Monitoring Station (CMS).

The Mass Balance requires transmitters (flow, pressure, temperature and density) at both ends of the pipeline and also shares the Central Monitoring Station (CMS).

Data communication is based on Modbus protocol and can be implemented using different links such as cable, radio, optical fiber, satellite, etc. Integration between ILDS and pipeline customer SCADA is easily implemented by means of an OPC driver embedded in the CMS.

In case of pre-existent instruments this integration allows retrieving the information from the SCADA such as, flow, pressure, temperature and density measurements, as well as on operational events such as valve operation, pump start/stop, operational changes, etc, to be used in the mass balance and validation module.

Main user interface functions are based on off-the-shelf supervisory package (such as iFix, Intouch or others) according to client preferences.
4 - Alarm Validation and Trend Analysis

Considering the complementary characteristics of the acoustic and mass balance technologies, based on data provided by both detecting techniques it is possible to have a better and wider evaluation of the pipeline operation scenario.

This is a unique advantage of the ILDS not featured by any other leak detection pack in the market.

The alarm validation and trend analysis module comprises special algorithms based on artificial neural networks (ANN) improving the overall system ability to distinguish real leaks from the various operational events such as pump start/stop, thus reducing dramatically occurrence and the rate of false-alarms.

Before the final alarm is issued for the user, the validation module cross checks the information coming from both detecting modules as well as analyzes other variables and trends. If all the conditions are coherent with a leak situation the alarm is then issued along all its related information (location, time stamp, leak rate, spilled volume, trends, etc).

5 - Summary of Features and Advantages (ILDS)

- Two complementary methodologies compliant to API RP 1130, Negative Pressure Wave & Mass Balance;
- Sophisticated signal processing including artificial neural networks and multi layer detection algorithms.
- Mass balance algorithms relying on Real Time Computational Fluid Dynamics (CFD) models;
- Precise line pack calculation including transient regimens;
- Real time cross parameters correction;
- Cross checking alarm validation and trend analysis;
- Adaptability to different operational conditions with learning capability;
- Easy integration to SCADA using OPC;
- High sensitivity and fast response time;
- Location accuracy better than 2% of the monitored length;
- Detects progressive and pre-existing leaks;
- Full sections coverage, from sensor to sensor, with no any mute zones;
- Detects leaks even with pipeline in shut-in condition;
- Complete leak report informing the leak location, time stamp, rate, spilled volume and graphical trends;
- Very Low false-alarm rate;
- Easy installation and set-up;
- Remote assistance and support.