SELECTING THE DETECTION METHOD FOR A REMOTE LEAKS DETECTION MONITORING SYSTEM AT ONSHORE OIL PRODUCTION FIELDS

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Abstract: Pipelines from onshore production fields have characteristics that accentuate leak detection problems. New initiatives on fast and accurate leak detection are critical for this type of scenario. In the literature there is a wide variety of leak detection methods developed and tested. With so much diversity of methods, the process of choosing a detection method for new proposed monitoring systems can become a challenging activity. Therefore, this article proposes a methodology based on six steps for defining the most appropriate detection method.

Keywords: pipelines, leak detection, onshore oil production fields.

SELEÇÃO DO MÉTODO DE DETECÇÃO PARA UM SISTEMA DE MONITORAMENTO DE DETECÇÃO DE VAZAMENTOS REMOTO EM CAMPOS DE PRODUÇÃO DE PETRÓLEO TERRESTRES

Resumo: Os oleodutos dos campos de produção terrestres têm características que acentuam os problemas de detecção de vazamentos. Novas iniciativas sobre detecção de vazamentos rápidas e precisas são fundamentais para este tipo de cenário. Na literatura, há uma grande variedade de métodos de detecção de vazamento desenvolvidos e testados. Com tanta diversidade de métodos, o processo de escolha de um método de detecção para novas propostas de sistemas de monitoramento pode tornar-se uma atividade desafiadora. Portanto, este artigo propõe uma metodologia baseada em seis etapas para definição do método de detecção mais adequado.

Palavras-chave: oleodutos, detecção de vazamentos, campos de produção de petróleo terrestres.

1. INTRODUCTION

New initiatives on fast and accurate leak detection are essential to the oil industry to stay competitive in a sustainable way. In onshore oil production fields, after extraction, the oil follows a network of pipelines to collection stations, where it is preliminarily treated before being sent to refineries. This network operates in remote areas, and it is often extensive, complex, and exposed to accidents, weather, and other environmental contingencies.

It is observed that although there is a wide range of leak detection techniques, the application of remote leak detection technology in flow and gathering pipelines in onshore oil production fields does not offer uninterrupted and real-time monitoring throughout of the line route.

Therefore, the Oil & Gas Industry is continually looking for more sensitive, accurate, reliable, and robust ways to meet the challenge of rapid leak detection. This article aims to describe the process of choosing suitable leak detection method for application in a remote monitoring system in production and collection lines in onshore oil production fields.

2. METHODOLOGY

There are several classifications of leak detection methods in pipelines, due to the use of different working principles and approaches [1]. Methods can be classified according to the degree of automation (automatic, semi-automatic and manual detection techniques) or intuitive degree of detection data (direct and indirect detection). Other approaches divide them into three categories: hardware-based methods, software-based methods, and biological methods [2] or internal systems, external systems, and visual systems [1,3].

Seeking to determine the most adequate leak detection method for defining and describing the specifications of a monitoring system for detecting leaks in pipelines in oil production in onshore fields, six basic steps were considered:

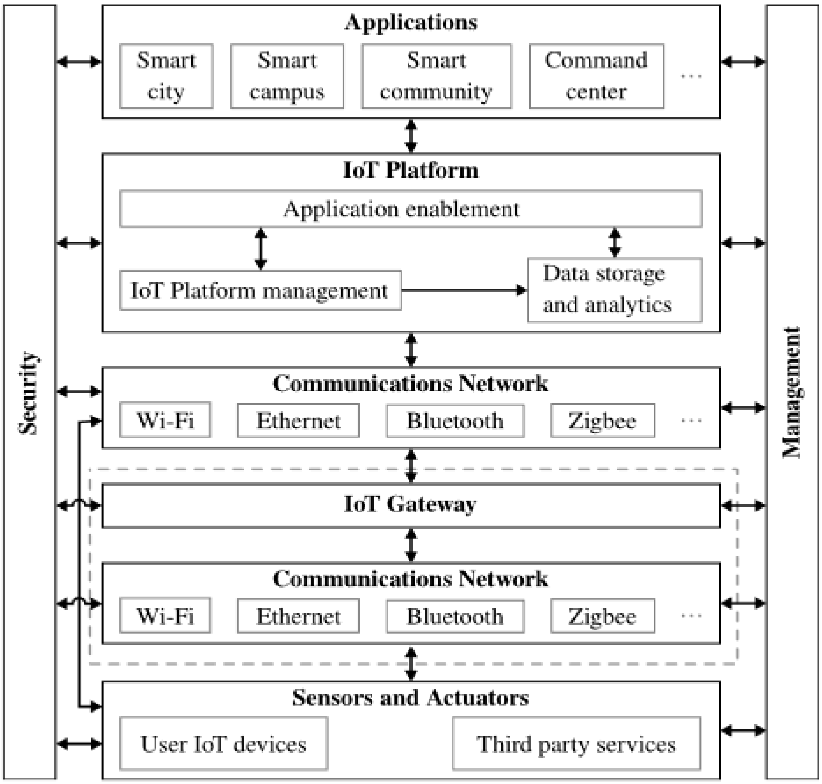
1. **Definition of the problem:** firstly, it must be clear what magnitude of the problem is to be solved.
2. **Definition of objectives:** then define the objective of the proposed system or the proposed solution to solve the problem.
3. **Characterization of the object to be monitored:** in this step, it is necessary to have knowledge of the main characteristics of the monitored object to select methods capable of recognizing such characteristics.
4. **Definition of sensing system requirements:** the requirements represent what is expected from the system. These are derived from current needs and their definitions are very important for decision-making on the most appropriate method.
5. **Analysis of sensing methods:** the research is carried out on the available methods, their detection principles, their advantages and disadvantages and the types of sensors available on the market for the problem under study.
6. **Choice of method and sensors:** finally, the decision is made on the sensing method that best meets the system requirements.

3. RESULTS AND DISCUSSION

A practical description of the steps proposed in Section 2 starts by the *Step 1 - Definition of the problem*. Oil production in onshore fields occurs, for the most part, in interior regions and mostly in the Northeast of Brazil [4]. These areas lack road and communication infrastructure, electrical networks, and telephone networks [5], which makes the flow monitoring of oil production a challenging activity. Although operators use a wide range of techniques for leak detection, the application of remote leak detection technology in these production and collection lines is rare or non-existent and does not offer uninterrupted and real-time monitoring along the route of the line.

In sequence, the *Step 2 - Definition of objectives* was done. In this case, an architecture for a monitoring system based on the Internet of Things (IoT) [6] was proposed as solution, in order to assist the detection of leaks in remote mode in oil pipelines for onshore production, as observed in Figure 1.

Figure 1. General IoT architecture to be applied for oil pipelines leak detection in remote mode.



Source: Domínguez-Bolaño et al. [6]

From this definition, the next step was the *Step 3 - Characterization of the object to be monitored*. In onshore oil production fields, there are two types of pipelines: flowlines and gathering pipelines. The flowlines are those connect to the wellhead. They transport a mixture of crude oil, gas, water, and solid waste from the well to central storage or field processing facilities. They are relatively short, with outside diameters ranging from 50 to 150 mm (2” to 6”), with low operating pressures to transport the content [7].

The gathering pipelines transport crude oil from the tank to a transmission pipeline. In some cases, they are directly connected to wells. They have a larger diameter, typically ranging between 100 mm and 400 mm (4” to 16”), and higher pressure is required to move the fluids. Flow lines and collection pipelines are commonly made of steel and externally coated to protect them from corrosion [7]. In most terrestrial fields these lines run for tens of kilometers, distributed in a complex network, and exposed to climatic conditions and other environmental contingencies over the years.

Based on these features, it followed to the *Step 4 - Definition of sensing system requirements.* To provide a reliable and applicable leak detection mechanism, the proposed method must meet the following requirements:

1. Provide safe and remote leak inspection.

2. Provide an automatic and autonomous leak inspection mechanism.

3. Be robust against environmental noise.

4. Be able to detect multiple simultaneous leaks.

5. Be able to detect the location of the leak.

6. Consider a method that depends as little as possible on the physical properties of the transported fluid and the material of the pipes, so that it can be applied regardless of the physical state of the fluid and the pipes.

7. Consider that production lines and collection lines transport multiphase fluids (crude oil, water, and gases).

Furthermore, the age of most pipelines makes securing the pipeline infrastructure a challenging prospect, so the sensors chosen to need to be robust and resistant to unexpected weather conditions as they will work in an open-air environment with humidity. variable, thus requiring a self-test and autocalibration system. The sensors also need to be robust and resistant to unexpected weather conditions, as they will operate in an open-air environment with variable humidity, thus requiring a self-test and autocalibration system. Ideally, the chosen sensor should be easy to use, otherwise, it is necessary to assume the need for training and qualifications for system operators. Another important point to consider is the cost of acquisition, installation, and maintenance, considering the reality of the onshore production fields.

After this context, the important step was the *Step 5 - Analysis of sensing methods*. The use of devices designed by physical principles in pipelines refers to hardware-based detection methods [8]. They are generally sensitive to small leaks and accurate regarding location. Typically, instrumentation runs along the entire length of the pipeline, which aids in detecting large and small leaks in a timely manner and allows detection of a leak anywhere along the pipeline.

The production fields under study use long pipelines, so the detection method to be chosen should be applied to long distance oil and gas pipelines. Among the methods, it is observed that only the following can be chosen: Acoustic Emission, Ultrasonic, Guided Wave Ultrasonic, Distributed Optical Fiber, SmartBall, Vapor Sampling, and Thermal Imaging [8]. The description of each method as well as their advantages and disadvantages for the scenario under study is shown in the Table 1.

Table 1. Overview of the sensing methods for oil pipelines leak detection.

Methods	Description	Advantages	Disadvantages
Acoustic emission	When a leak occurs, the acoustic signal and the background noise reach the sensors and are compared with the profiles of acoustic wave signals present in the system [9].	The detection has higher sensitivity and accurate positioning [4]. Easy to use and install as it does not require system shutdown for installation or calibration [1].	The effect of noise from other sources can easily mask the actual leak sound [1]. In addition, the type of piping material interferes with leak recognition.
Ultrasonic	The ultrasonic method is characterized by being hardware-based, acoustic and non-invasive. A common way of applying the technique is to use a pulsar, a transducer, and a device to display the captured signals [10].	Fast response and high sensitivity and low detection cost and low power consumption [8].	Its implementation requires extensive knowledge and careful application by experienced technicians. Couplants are required to provide effective transfer of energy between the transducers and the piping. Reference standards are also needed, both for equipment calibration and for fault characterization [10].
Guided Wave Ultrasonic	For leak detection, a ring of piezoelectric transducers is installed around the duct. When there is a need to carry out the inspection, a device is attached that controls the transducers, causing them to emit pulses and receive them back [11].	Shorter inspection time and less labor demand and presents itself as a great proposal to monitor long lengths of pipeline, due to the ability of guided waves (lamb waves) to propagate in materials such as steel [8].	Currently there is little variety in the market for standard devices and have high cost. Another difficulty is related to data processing: defining the ideal frequency for the emission of guided waves and comparing it with the received signals is a process that requires specialized technical knowledge. It requires a pre-calibration.
Distributed Optical Fiber	The most common choice of fiber optic sensors in hydraulic applications is scattering-based (Rayleigh and Brillouin scattering-based sensors) and wavelength-modulated (fiber Bragg grating) [12].	The sensors require no electrical power and have low optical transmission losses and little signal decay. The same fiber can be used to detect and transmit information [12].	Interference required in the pipes to install the sensors.
SmartBall	Comprehensive sensing technology that includes an array of acoustic sensors, accelerometers, magnetometers, ultrasonic transmitters, temperature sensors, and more. These sensors roll inside the pipe following the fluid flow [8].	The technology can be used for pipes of any material and the sensitivity of leakage detection is high [8].	Under different working pressures, the minimum detectable leakage of the SmartBall is different. The presence of an operator is required to insert the SmartBalls, in addition to the limitations of internal access to pipes with junctions, diversions and manifolds, characteristic of oil production fields.
Vapor sampling	It consists of taking hydrocarbon vapor samples near the monitored pipeline to determine the oil leak based on the measured gas concentration. This method can use a vapor monitoring system or mobile detector device [8],[13].	This technique is particularly suitable for detecting small concentrations of diffuse gas [8].	The cost is high and requires many sensors in long pipelines [13]. Gases such as biogas in the soil may cause false alarms [8].
Thermal Imaging	The method uses an infrared camera to analyze changes in thermal radiation around the pipeline [8] in the infrared range of 900 –1400 nanometers [14].	Increasing use of technology for remote monitoring of unmanned plants. market trend for the search for visual solutions. The technique is not affected by the materials or sizes of the tubes and their connections.	Area surface conditions, solar radiation, cloud cover, and ambient temperature can impact the capabilities of this method [15].

Source: own authorship

At last, the *Step 6 - Choice of method and sensors* was done. Considering the sensing methods listed, most of the analyzed methods are based on the physical properties of the fluid, the pipe's material or on process parameters such as pressure, velocity, and temperature. Based on the desired requirements above and on the advantages and disadvantages of applying each detection method described, the thermal image leak detection method was chosen as it does not depend on the complexities identified in physical characteristics and environmental restrictions. Furthermore, thermal cameras have been used as a remote inspection method in several industrial applications and have been evaluated as a facilitator in automatic inspection, in the case, leak inspection, constituting a system that is robust to environmental noise and capable of detecting small leaks.

4. CONCLUSION

The procedure of sensing method selection based on the literature review of oil and gas pipeline leak detection methods was conducted to identify a suitable method for monitoring system in production and collection lines in onshore oil production fields. In the process of analyzing the advantages and limitations of each method based on the defined requirements, the thermal imaging method through the application of infrared thermal cameras was selected for facilitating the automatic inspection/detection of leaks, constituting a robust system environmental noise, in addition to being able to detect small leaks.

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