Spontaneous leak detection as a subscription service

How IoT and digitalization are transforming data-driven leak detection methods to meet new E&P regulations

Authors

- Michael Nicolaas Jansen van Rensburg, Siemens Energy
- Stuart Mitchell, ProFlex Technologies

Spontaneous pipeline leaks have always posed environmental, health, and safety (EHS) as well as financial risks to the oil and gas industry's entire value stream. Yet as expectations grow to significantly minimize environmental impacts and improve sustainability measures, today's pipeline operators — particularly companies with older pipeline infrastructures — are facing even greater scrutiny from stakeholders, activists, and regulatory bodies. With roughly half of the 2.6 million miles of gathering, distribution, and transmission lines in the U.S. over 50 years old, a robust leak detection strategy ranks high on the priority list for most operators stateside [1)].

What's more, the Pipeline and Hazardous Materials Safety Administration (PHMSA) issued new rules expanding the use of leak detection integrity management (IM) and safety requirements to "make better use of all available data to understand pipeline safety threats" in all regulated, non-gathering hazardous liquid pipelines [2)].

Correctly detecting leaks in both new and existing pipe networks has traditionally been a challenging and costly task. However, the recent introduction of digitalization and Internet of Things (IoT) technology to the current detection methodolgies have unlocked new data-driven techniques and engagement models to make leak detection more cost-effective, reliable, and easier to deploy.

Leak Detection Challenges

The aforementioned PHMSA regulations come as no surprise. With nearly 3,000 serious pipeline accidents in the past ten years — defined by fatalities, injuries, fires, explosions, or liquid releases of 50 bbls or more — amounting to over US $7 billion lost, the expanded leak detection regulations are clearly intended to reduce EHS risks in the field [3)]. But as operators work to ensure compliance with these new rules, they are faced with the inevitable question of cost.

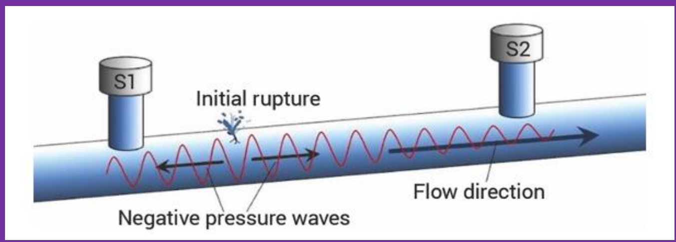
While minimizing leaks have always been a priority for pipeline operators, the methods of doing so have been limited in both efficacy and expense. Mass-volume balance calculation, which measures and compares the volume of product as it passes through different meters en-route, continues to be the most commonly used technique. It does

Negative Pressure Wave (NPW) Detection

The basic concept of NPW is based on the principle that when a leak occurs in a pipeline, the pressure of fluid local to the leak location in the pipe drops, and a pressure wave signal (known as a negative pressure wave) propagates outwards from the leak point.

The pressure wave signals then travel through the pipeline section which are detected by pressure transducers stationed at positions along the pipeline. The location of the leak can be estimated by applying a cross-correlation method to the time difference at which the pressure transducers see the leak event, providing accurate localization to as little as +/- 20 feet.

By combining complex event edge detection algorithms with signal filtering and positional confirmation, the system is able to accurately detect the occurrence of a leak event without triggering a material level of false positive events.



not, however, constitute a comprehensive leak detection strategy. It frequently fails to detect small leaks and provides too vague of localization to help dispatched technicians in trucks or aerial drones/UAVs outfitted with specialized cameras locate the leak between metering stations — which can be tens or even hundreds of miles apart — in a timely manner.

Other leak detection methods including vibroacoustic monitoring with accelerometers, pressure point analysis, and dynamic model-based detection, which have all been used with varying degrees of success. The most accurate detection method, fiber optic sensing, also costs the most. Laying fiber optic cables, especially for older transmission lines and rugged terrain routes, demands significantly higher CAPEX costs than other modern techniques. What's more, the fiber optic cables ultimately become another piece of equipment operators must maintain and repair over time.

Real-time leak detection as a turnkey, subscription-based managed service

Today, Negative Pressure Wave (NPW) based leak detection is emerging as an extremely cost-effective and real-time technique, especially among operators whose capital budgets have shrunk during the recent low-price market environment. Simply put, when a spontaneous leak occurs, a rapid decrease in oil or gas density creates a negative pressure wave from the leak location that disseminates along the path of product flow in both the upstream and downstream directions. Installing specialized sensors (i.e., nodes) at multiple locations along the pipeline enables a more precise location (to within +/- 20 feet) to be determined from measuring the time it takes for a wave to reach a sensor. As the pressure wave travels at a high rate of speed, leaks can be detected within seconds, as seen in Figure 1.

NPW-based sensing has emerged as the strong contender to meet the expanded PHSMA regulations not only for its fast detection capabilities but also for not requiring any capital expense, thanks to Siemens Energy's subscription-based service.

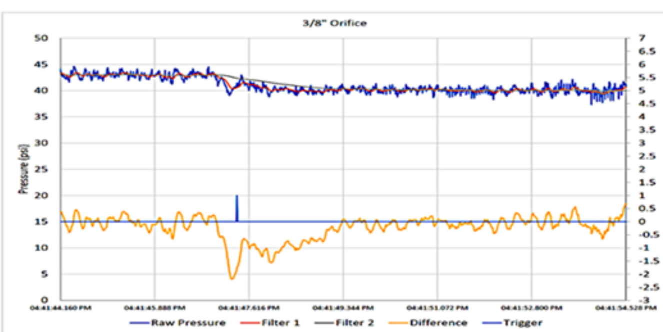


Figure 1. Enhanced negative pressure wave detection identifies leaks within seconds.

NPW sensing requires minimal hardware and no interruptions to service, making it easier to deploy in both brownfield and greenfield applications. For long-distance transmission lines, nodes are installed via hot tapping access points. Other variables, such as the fluid characteristics of the product, the size of the line, pressure, and leak size, also determine how far sensors can be placed. For a natural gas or crude transmission line, for example, nodes can be installed roughly every 15 to 30 miles.

Though both fast and cost-effective, NPW-based detection was historically known to produce a high rate of false positives. Within the pipelines, the organic flow of fluid causes an extremely dynamic environment that can result in constant small pressure fluctuations. This background "noise" can make detecting spontaneous leaks challenging and used to require an amount of advanced signal processing and data filtering methodologies.

But as we arrive fully at the age of digitalization, significant advancements in analytics and cloud computing have improved signal processing and dramatically reduced the incidence of false positives. IoT -enabled, NPW-based detection now stands as the best available technology for spontaneous leak detection.

Meeting new requirements with new technology and services

The IoT architecture of today's NPW-based detection solutions enable new engagement models that are so flexible, operators' upfront capital investment requirements are all but eliminated. For example, the Siemens Energy Spontaneous Leak Detection (SLD) Service, powered by ProFlex Technologies, leverages edge nodes and cloud technology to optimize leak detection and help operators more nimbly respond to new and future regulations in four distinct ways:

- **Increases speed:** Detects leaks in seconds to help minimize environmental damage.
- **Accurate localization:** Pinpoints leak coordinates within +/- 20 feet, reducing the cost and time of finding and repairing leaks.
- **Minimizes product loss:** Identifies leaks typically as small as 0.5 to 2.0 inches in order to react quickly to reduce product loss.
- **Layered security:** Supplements existing leak detection systems for critical pipeline sections.

Leveraging the NPW-based remote pressure monitoring and complex data processing algorithms of ProFlex Technologies, the SLD Service rapidly detects and localizes small pipeline leaks before sending data to the Siemens Energy cloud, where it is analyzed in real-time. The ProFlex-enhanced NPW signal processing is then distributed between the edge nodes and the cloud, with notifications sent to users through mobile devices, laptops, desktops or through SCADA systems. The basic SLD Service technology architecture is shown in Figure 2.

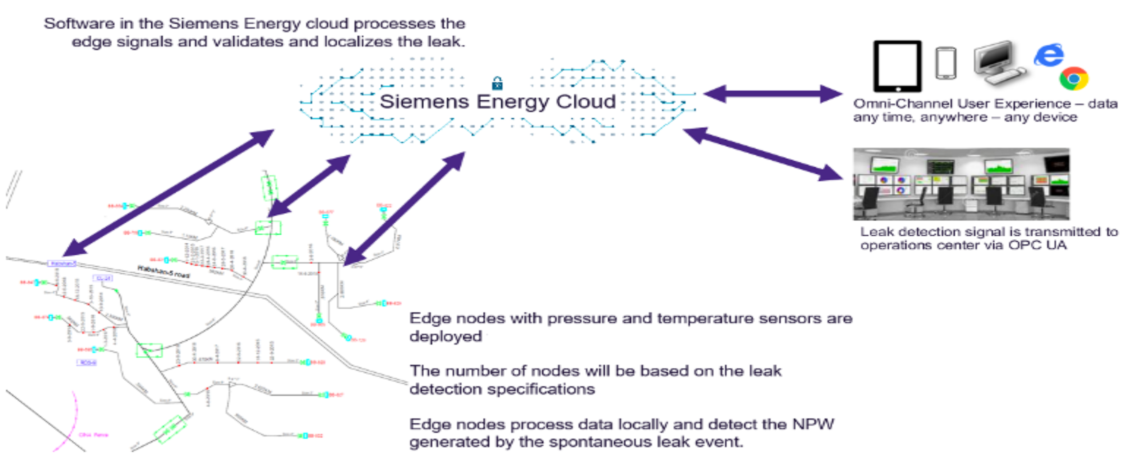


Figure 2. Siemens Energy SLD Service Architecture, powered by ProFlex Technologies

Moreover, the Siemens Energy SLD Service, as mentioned, is offered as-a-service. This eliminates capital expense and also minimizes the impact on pipeline operations and staff. That's because design, installation, commissioning, operation, and maintenance of the service are fully managed by Siemens Energy, all on a turn-key, subscription basis, so costs can be accounted for as operating expenses.

Once the SLD Service edge nodes are installed and operational, there is additional "calibration" of the signal processing algorithms to the specific pipeline operational characteristics and will be subsequently tuned over the course of the subscription. Able to be deployed in virtually any brownfield or greenfield pipeline application, including water, hydrogen, hazardous materials, and other multi-phase flows, SLD Service is a viable solution for production gathering networks, multi-node systems, process plants, and offshore production risers.

Current deployment of SLD Service has shown to reduce operating expenses by up to 25 percent. Though Siemens Energy maintains the technology for the life of the subscription, thereby reducing upkeep and tuning costs, the majority of cost savings comes from the ability to detect and accurately localize serious leaks faster, translating to significantly reduced repair time and costs. Faster repair times increase overall field uptime, ultimately resulting in increased year-over-year production.

Layered security offers a safer, more resilient leak strategy

Though most modern leak detection solutions including SLD Service can be deployed as standalone solutions, a multi-layered approach can significantly lower the risk of an unplanned product release. Of course, there is no one-size-fits-all solution when a pipeline travels hundreds of miles. Operators must evaluate when and where it is economical to implement multiple leak detection methods. Many pipeline routes through densely populated urban areas or close to protected lands and must double or triple its leak detection strategy to ensure safety guidelines and regulations are met. In such cases, the SLD Service can be combined with other methods such as mass balancing or point pressure analysis for greater resiliency.

In any E&P application, personnel safety remains a top priority. Deploying cost-effective and widely available leak detection methodologies such as NPW-based SLD Service can ensure personnel safety by identifying hazardous product releases sooner to reduce the risk of serious personnel harm.

As the industry moves towards a greener and more sustainable future, regulations will continue to evolve and with it, the need to keep aging infrastructure up to code. Detection solutions that are flexible, scalable, and able to be layered will become even more critical to ongoing regulatory compliance. Using an 'as-a-service' solution such as Siemens Energy SLD, powered by ProFlex Technologies, operators can continue to benefit from improvements and innovations in computing power, sensor technology, and communications technology. By partnering with a service-oriented solutions company like Siemens Energy, they can be assured the technology will continue to serve their needs well into the future.

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onshore-solutions@siemens-energy.com