SIEMENS-PROFLEX SPONTANEOUS LEAK DETECTION SYSTEM

Endorsement Report

Siemens Energy

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Objective: Technology Endorsement for Siemens-Proflex Spontaneous Leak Detection System (SLDS) including performance metrics such as accuracy, sensitivity, and reliability for liquid, water, and multiphase applications.

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1 EXECUTIVE SUMMARY

Siemens Energy Inc. (Siemens Energy) has asked DNV GL USA Inc. (DNV) to perform an independent 3rd party evaluation for their proprietary Leak Detection system, i.e., Siemens-Proflex Spontaneous Leak Detection System (SLDS).

Based on (1) thorough review of the documentation provided by Siemens Energy, and (2) discussion and clarification workshops between DNV Subject Matter Experts (SMEs) and design/operation engineers from Siemens Energy, DNV endorsed that the Siemens-Proflex SLDS is suitable for applications used in hydrocarbon liquid, water, and multiphase flow media under different pipeline operational states including steady state and shut-in mode. Details of the SLDS performance metrics (accuracy, sensitivity, robustness, and reliability) are described in Table 5-1.

2 INTRODUCTION

2.1 Background

DNV was engaged by Siemens Energy to assist with an independent 3rd party evaluation of their proprietary spontaneous leak detection system, i.e., SLDS.

This report details the scope of work, assumptions, limitations, and recommendations for future work.

2.2 Technology Endorsement Overview

DNV is involved in verification and classification of concepts and equipment for use in the oil and gas industry. Developments in the industry mean that new technology is frequently being introduced to the market to improve on existing technology or to permit the industry to move into new areas of oil and gas exploitation. On one hand, use of new technology introduces new challenges to ensure that the technology will be able to perform as intended and will do so in a safe manner.

On the other hand, for concepts or systems which embody a significant level of novelty a standard review process, with respect to existing codes and standards and Class Rules may not be an approach which will satisfactorily address all relevant aspects. Novelty in this context involves design or operational aspects for which there is no industry experience. It may involve design features not previously developed or application of known design features in a manner not originally envisaged for such a feature.

In developing either rules or international codes and standards assumptions are made with respect to applicability. While applying the principles on which these standards were developed may permit a certain amount of extrapolation where concepts exceed the limits of the intended application, there will come a point where the requirements are no longer suitable and may be either overly conservative or insufficiently conservative. In other cases, no code or standard has been developed to address the particular design.

Given the fact that existing requirements/standards will not be fully applicable, DNV applies the Technology Endorsement approach for assessing such novel designs.

The Technology Endorsement approach is an evidence-based independent 3rd party evaluation including both performance review and risk assessment. The objective of technology endorsement is to (1) confirm the performance metrics with specific boundary conditions for the technology under assessment; (2) ensure all potential risks/barriers that may prevent the technology to perform its intended functions with specified performance criteria are mitigated or addressed. The Technology Endorsement approach provides a structured, traceable approach to document the performance of novel concepts or technology.

3 BASIS FOR WORK

3.1 SLDS Overview

From the data, information, and documents received from Siemens Energy, SLDS can detect spontaneous leaks in pipelines, gathering systems and offshore risers. A spontaneous leak is an event that causes an immediate breech in the pipeline. As an example, an excavator digging near a pipeline hits the pipeline and causes a breech. This is different than a creeping leak such as a leaking seal where product is lost slowly over time.

SLDS utilizes complex data analysis algorithms to detect the pressure events associated with a pipeline leak event, with the pipeline continuously monitored for pressure and temperature changes by distributed sensor nodes.

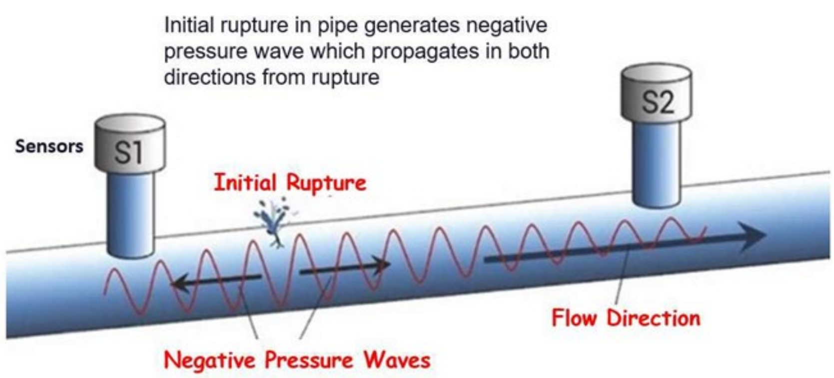
Once a leak event is detected by an Edge Node, the Edge Node sends time-stamped data to the Siemens Energy Azure cloud for processing. Each Edge Node acts independently in detection and transmission of a possible leak event. The Siemens Azure cloud has additional algorithms to compare data received from independent Edge Nodes to determine if there is a leak event. A valid leak event is confirmed if two or more Edge Nodes detect an event within a predetermined time. Once the cloud algorithms determine that a valid event has occurred, additional processing is done to map the location of the leak. This location is then plotted on the pipeline map in the Siemens Energy Azure Cloud and notification of the event and location is sent via email and SMS to the concerned contacts. Each customer pipeline and this test loop has a detailed pipeline map created in the Siemens Energy Azure Cloud, which shows relevant devices and infrastructure.

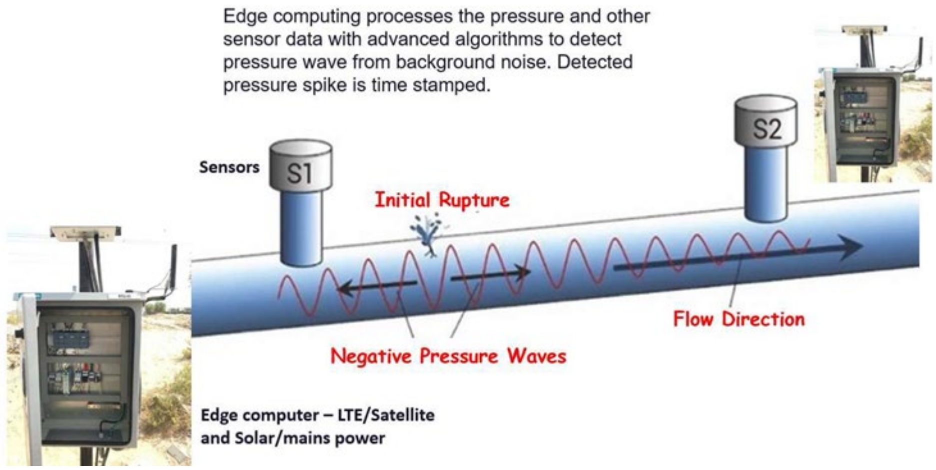
By combining complex event edge detection algorithms with signal filtering and positional confirmation, the system is able to prevent false positive alarms from pipeline system noise events such as pump and valve operation.

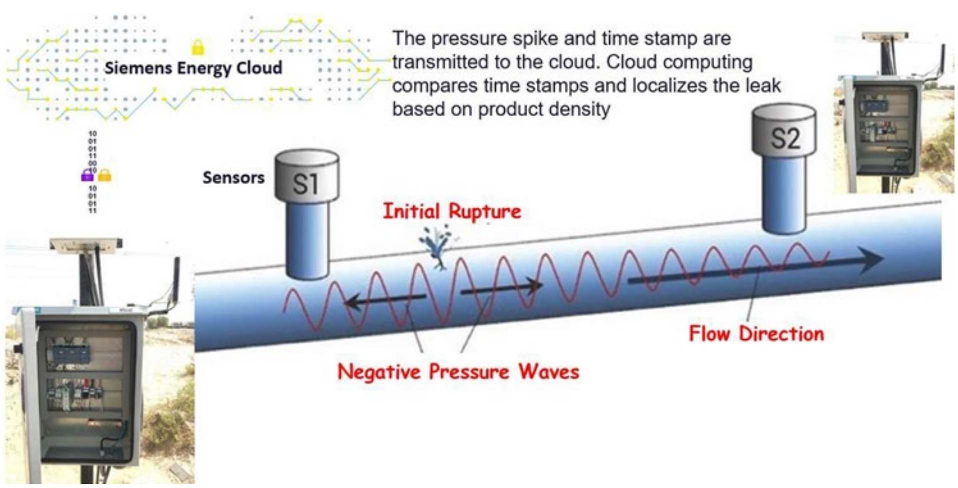
SLDS leverages continuing improvements in sensors, computing power, and communications technology combined with the improved/newly designed algorithms from ProFlex to detect the negative pressure wave created by a spontaneous leak from the background pipeline "noise." By analysing pipeline behaviour and applying signal filtering approach for each individual pipeline and by continuously updating algorithms according to changes in pipeline flow parameters, the ability to identify and pinpoint spontaneous leaks is achieved.

SLDS' modified negative pressure wave detection process is described in Figure 3-1 below:

Figure 3-1 Siemens-Proflex Leak Detection System Leak Detection Process







SLDS consists of edge computing node hardware located at regular intervals, 10 to 20 miles, along a client's pipeline. In addition, a high sample rate pressure transducer is used to detect the negative pressure wave pulse, it also utilizes a temperature sensor and density meter to characterize the fluid in the pipeline. Combining these inputs with proprietary engineered leak detection algorithms, the leak event can be detected and then sent to the cloud-based service for further processing.

3.2 SLDS Documentations

Siemens Energy submitted total of 7 documents to DNV for review, the documents given in Table 3-1 form the basis for the independent 3rd party evaluation for SLDS.

Table 3-1 Documentation for Technology Endorsement

Ref.	Issued Year	Document Name
1	2021	Siemens-Proflex Leak Detection System Documentation for DNG-VL Endorsement Certificate
2	2019	PRF-APA-001-001-REP-R1 Pipe-Safe Field Trial Report
3	2019	PRF-QEP-001-002-REP-R1 Pipe-Safe Field Trial Report
4	2021	PRF-TST-001-001-REP-R1 Test Loop Leak Location Report
5	2019	PET-IDE-001-001-REP-R1 Pipe-Safe Pipeline Blockage Detection
6	2021	DNV Doumentation- Overview
7	2021	Tesing and Initial configuration

4 INDEPENDENT 3RD PARTY EVALUATION FOR SLDS

4.1 Scope

The technology endorsement scope consists of two main phases:

- Phase I: In accordance with the requirements of API recommended practices regarding the performance of leak detection systems (API 1130, API 1149, etc.), DNV SMEs performed a thorough review of documentation provided by Siemens Energy, see Table 3-1 for details. Based on the documentation review results, DNV SMEs categorized the application boundaries for SLDS, i.e., applicability in different systems (such as Pipelines, gathering systems, offshore risers, etc.), applicability in different media (such as liquid, gas, and multiphase flows), applicability in different pipeline operational states (such as steady state, transient state, and shut-in mode); map SLDS performance metrics for various applications and identify gaps.
- Phase II: conduct workshop with participants from Siemens Energy and DNV to discuss the results and the gap closure plan.

In phase I, accuracy, sensitivity, reliability, and robustness, which are the four important performance metrics that are usually evaluated for leak detection systems, were selected for the independent 3rd party evaluation for SLDS. Accuracy usually refers to detecting the location of the leak within the claimed location uncertainty, sensitivity refers to detecting different sizes of leaks including ruptures and pin-hole size leaks in proper time windows, reliability refers to generating minimum false alarms while meeting the claimed sensitivity targets, and robustness refers to being functional as intended even in abnormal events.

4.2 Technology Endorsement Details

4.2.1 Accuracy and Sensitivity for Applications in Hydrocarbon Liquid pipelines

Based on "*PRF-QEP-001-002-REP-R1 Pipe-Safe Field Trial Report*" (ref/3/), where five test trials were performed for QEP Resources Inc. at their Mustang Springs location, DNV confirmed that the Siemens Energy SLDS detected leaks for hydrocarbon liquid pipeline with an accuracy of +/- 30 ft in a steady state operation of the pipe. For sensitivity, based on the availability of the measurement data, an approximate estimation can be derived from the ratio between leak hole size/diameter and pipe diameter. Since this estimation results in larger values (more conservative) than the accurate estimation of the sensitivity where the hole size, process conditions and the system configurations (boundary conditions) are all considered, the estimation method is acceptable for the technology endorsement purpose. With this approximate estimation, sensitivity for SLDS under liquid application under steady state condition is approximately 0.17% within 3 seconds.

4.2.2 Accuracy and Sensitivity for Applications in Water systems

Based on "*PRF-APA-001-001-REP-R1 Pipe-Safe Field Trial Report"* (ref/2/), where five test trials were performed for Apache company at their Schrock Water Line location, DNV confirmed that the Siemens Energy SLDS is capable of detecting leaks in water system applications with an accuracy of +/- 30 feet under steady state condition. Based on the available measurement data in this report, the sensitivity for SLDS in water system applications for the steady state condition is approximately 0.063% within 3 seconds.

Based on "*PRF-TST-001-001-REP-R1 Test Loop Leak Location Report" (*ref/4/) where test loop was constructed at the Siemens Energy Telge Road location, and five test trials were performed, DNV confirmed that the Siemens Energy SLDS is capable of detecting leaks in water systems with an accuracy of +/- 30 ft under steady state condition. Also, by adopting approximate sensitivity estimation method, sensitivity for the SLDS in Water applications for the steady state scenario presented in this report was approximately 0.39% within 3 seconds.

Based on "*PET-IDE-001-001-REP-R1 Pipe-Safe Pipeline Blockage Detection*" (ref/5/), where five test trials were performed by Petrobox for Ideal Energy Solutions at an East Texas field location, DNV confirmed that the Siemens Energy SLDS is capable of detecting leaks in applications for Water with an accuracy of +/-16 ft across the total length of 3250 ft of pipe segment under shut-in mode of the pipe segment. Sensitivity of SLDS under Water application for the shut-in mode was approximately 6.25% within 3 seconds.

4.2.3 Accuracy and Sensitivity for Applications in Multi-phase Flow

Based on "*PET-IDE-001-001-REP-R1 Pipe-Safe Pipeline Blockage Detection*" (ref/5/), five test trials were performed by Petrobox for Ideal Energy Solutions at an East Texas field location. During the field trials, the fluid composition had a gas content of 2.5% volume and a crude oil content of 97.5% which was considered as the multiphase flow for the purpose of this assessment. Note that the conclusion in this section is only valid for this combination of gas and crude oil and may not be applicable for other mixtures. From the trial results obtained for this particular multiphase mixture, DNV confirmed that the Siemens Energy SLDS can detect the location of the leak with an accuracy of +/-16 ft in the total length of 3250 ft of pipe segment under shut-in mode of the pipe segment. For sensitivity, based on the availability of the measurement data, approximate estimation method was adopted and hence the sensitivity of SLDS under applications with this multiphase mixture in the shut-in mode is approximately 6.25% within 3 seconds.

4.2.4 Assessment of Reliability and Robustness for SLDS

Two workshop sessions were conducted with SMEs from DNV and design and operation engineers from Siemens with following objectives:

- Discuss SLDS performance gaps based on the documentation review performed by DNV SMEs.
- Ensure all potential risks/barriers that may prevent the SLDS to perform its intended functions with specified performance criteria are mitigated or addressed.

During the documentation review, one major gap was identified by DNV SMEs, i.e., reliability of SLDS. Siemens Energy team explained the existing designs of SLDS does provide specific means to minimize false alarms, such as:

- Additional algorithms by Siemens Azure cloud to compare data received from independent Edge Nodes to determine if there is a leak event.
- A valid leak event is confirmed if two or more Edge Nodes detect an event within a predetermined time.

However, the system did not generate any false alarms during the fluid withdrawal test (FWT). Therefore, DNV suggests that the SLDS system needs to be tuned for each specific application to ensure minimum false alarm rates, and DNV proposed the following actions as the gap closure plan:

1. Define a target for false alarm rate.
2. For each specific application/pipeline system, develop installation, configuration, and commissioning plan, and routine maintenance program (including tuning) to ensure the system can meet the reliability target.

Later, Siemens Energy provided additional documentation, "*Testing and Initial Configuration*" (ref/7/), which closed out the action #2, except for the tuning part.

During the workshops, robustness of SLDS was evaluated from four aspects, communication, hardware, software and interface with client systems. For each aspect, potential barriers were identified, and the existing mitigation/design controls along with corresponding documentation evidence were examined. The details are described in Table 4-1.

Table 4-1 SLDS Robustness Assessment Details

Evaluation Aspects	Potential Barriers	Mitigations/Design controls	Documentation Evidence
Communication	Communication outages (interconnection failure)	Multiple communication methods available, LTE (multiple SIMM cards), ethernet and satellite; industry proven equipment; Health Check to confirm the status with hardware diagnostics;	DNV Documentation-overview
Hardware	Edge computing node malfunction	Every node is independent and when one edge node is down, Health Check will report the failure status, and one failed node will not compromise the detection capability	DNV Documentation-overview
	Temperature sensor malfunction	Health Check to confirm the status with hardware diagnostics;	DNV Documentation-overview

Evaluation Aspects	Potential Barriers	Mitigations/Design controls	Documentation Evidence
	Densitometer malfunction	Edge computing node is capable of calculating the density info; location accuracy might be compromised, Health Check to confirm the status with hardware diagnostics;	DNV Documentation- overview
	Pressure transducer malfunction	Health Check to confirm the status with hardware diagnostics;	DNV Documentation- overview
Software	Cloud algorithms malfunction	Siemens cyber security along with client cloud;	DNV Documentation- overview
interface with client system	Compatibility issue	Commissioning test/FAT to check compatibility; Simulation test at client pipeline	Siemens Energy Testing and Initial Configuration Document, DNV Documentation- overview
	Adverse impact to pipeline operation	Implementation of the system has minimal impact on the pipeline operation and the pipe does not have to be shut down/interruption due to installation of the leakage detection system. Sensors only require a small-bore fluid connection to pipeline from a riser or block valve.	DNV Documentation- overview

5 CONCLUSION

Based on the thorough review of documentation provided by Siemens Energy (Table 3-1), and discussion results from two workshop sessions, as a reputable independent third party, DNV endorses the following performance metrics for Siemens Energy SLDS:

Table 5-1: Endorsement Details for Siemens Energy SLDS

Performance Metrics	Liquid	Water	Multiphase Flow
Steady State			
Accuracy	+/- 30 ft	+/-30 ft	N/A
Sensitivity	Approximate 0.17%* within 3 seconds	1. Approximate 0.063%* within 3 seconds (field trial) 2. Approximate 0.39%* within 3 seconds (test loop)	N/A
Shut in mode			
Accuracy	N/A	+/-16 ft in the total length of 3250 ft of pipe segment	+/-16 ft in the total length of 3250 ft of pipe segment
Sensitivity	N/A	Approximate 6.25%* within 3 seconds	Approximate 6.25% leak rate within 3 seconds

*The sensitivity estimation was derived from the ratio between leak hole size/diameter and pipe diameter.

5.1 Next Step

Once Siemens Energy conducts more field trials in other applications, operational modes, and media (such as gas medium, transient state, slack line for various application, etc.), the endorsed performance metrics will be evaluated and added to the list on Table 5-1.

As described in Section 4.2.4, prior to each field installation of SLDS, DNV suggests that Siemens Energy should work with their clients to first define target false alarm and then tune the SLDS system for each specific application to ensure minimum false alarm rate.

5.2 Limitations and Conditions

The evaluation is valid for the system as it appears in the submitted documents, see Section 6 Reference. Any alterations to the system shall be evaluated by DNV on a case by case basis before being considered accepted.

The endorsed performance metrics for the multiphase flow application of SLDS are only valid for the combination of gas and crude oil used in the field trial and may not be applicable for other mixtures.

6 REFERENCE

Ref.	Issued Year	Document Name
1	2021	Siemens-Proflex Leak Detection System Documentation for DNG-VL Endorsement Certificate
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