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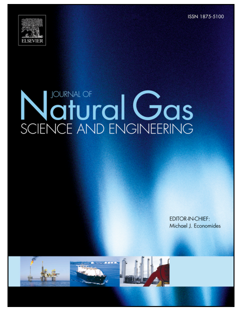

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Leak Detection in Low-Pressure Gas Distribution Networks by Probabilistic Methods ☆

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Abstract

The presence of leaks is a prevalent issue for aging gas distribution systems across the globe. These events, if not detected in time, may bring about environmental and health hazards, besides economic losses. Therefore, the development of efficient detection, quantification, and localization methods is crucial to all gas companies worldwide. In this paper, we present a leak monitoring system, called *Leak Analytics System* (LAS) using a probabilistic approach to determine the location and the rate (severity) of leakage in low-pressure gas distribution networks. This work aims to develop a robust, cost-effective, and real-time online monitoring system for low-pressure gas distribution networks. The leakage events are estimated using pressure and flow data obtained from steady-state modeling of the gas network. The robustness of the methodology is illustrated by analyzing gas networks in the presence of measurement errors, which account for unavoidable sensor noise in flow and pressure data. The feasibility of the proposed method is demonstrated on a small artificial gas network. Moreover, the method is applied to a section of the Singapore gas distribution network for a single as well as multiple leak scenarios. It is also experimentally shown that the severity of the leak and the location for a single leak scenario can be determined within an accuracy of 95% and 80% respectively, even in the presence of strong noise.

Keywords: Leak detection, Localization, Severity, Gas distribution network, Pressure, Flow.

Nomenclature

$\hat{n}_\ell$	Number of nodes in leak zone
A	Demand junction link incidence matrix
B	Link loop incidence matrix
D	Inner diameter of the pipe (mm)
g	Specific gravity of gas
L	Pipe length (m)
m	Number of branches (pipes)
n	Number of nodes
n_ℓ	Number of dummy nodes (zero demand nodes)
P^*	Pressure at pressure regulator node
P_i	Pressure at the node i
q	Flow demand vector at the outlet nodes
Q_j	Gas flow inside the pipe j
r_i	Residual at monitoring location i
S	Node sensitivity matrix

1. Introduction

Pipeline networks are one of the vital and economically effective modes of transportation of natural gas. These networks are complex system and continuously expanding with hundreds or thousands of kilometers of pipelines every year. Gas pipeline networks are mainly classified into transporting networks and distribution networks. Transporting networks operate at very high pressure (>1.6MPag) which transport gas from coastal supplied to regional areas. On the other hand, distribution networks operate at medium (50kPag-0.3MPag) to low-pressure (0-50kPag) and distribute gas from regional areas to end customers.

The failure of any of the pipeline network system leads to not only the loss of natural resources but also causes serious environmental impact and threat to public safety. Therefore, it is essential to manage pipeline risk, prevent and mitigate the consequences of any failures (Muhlbauer, 2004) such as leaks. Several approaches have been applied to identify possible pipeline failure initiators and subsequently perform risk assessment (Veritas, 2010; Hopkins et al., 2009). Risk assessment analysis for pipeline failures are based on qualitative and quantitative methods (Han and Weng, 2011; Jo and Ahn, 2005) such as probability and statistics methods, analytic hierarchy methods, fault tree analysis, event tree analysis, etc. According to (Pennenergy, 2016), most systems that constitute these pipeline networks across the globe are between 30 and 100 years old. Hence, aging and lack of maintenance have increased the risk of failures such as leaks in the pipes (especially at the joints), which if not detected in time can cause substantial financial loss and can lead to major accidents. These pipes are therefore propelling the need for more reliable leak detection across the pipeline industries worldwide.

Due to maturity of transporting networks, several leak detection techniques have been developed for its continuous monitoring (Billmann and Isermann, 1987; Zhang, 1997). (Ma et al., 2010) applied the negative pressure wave method that exploits the pressure waves generated by leaks while (Rocha, 1989) explored the appearance of acoustic pressure waves caused by

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