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天然气站场泄漏扩散源项反演方法研究

摘要

当有害气体意外释放后，准确、高效的源项估计方法对确保天然气站场的安全平稳运行至关重要 [1]。合理的传感器布置作为源项估计（Source term estimate，STE）的基础，直接影响到了 STE 方法的精度。现有的传感器布置方法大多都只针对特定工况且需事先了解泄漏来源，这在 STE 工作中是不切实际的 [2]。加之现有的 STE 方法实时性差，难以应对动态场景 [3]。本文提出一种天然气站场泄漏的传感器优化配置方法和 STE 深度学习模型，用于实现复杂结构和风向条件下泄漏点强度和位置的快速精准估计。该模型引入信息熵理论 [4]，建立了多目标工况下的目标函数用于优化传感器配置，并将风向频率作为权重系数引入到目标函数中，通过遗传-粒子群全局优化算法（GA-PSO）实现了复杂风向条件下的最优化配置 [5]。在此基础上，搭建天然气泄漏扩散实验平台和 CFD 模型，构建了 BiTCN-BiGUR 的双向深度神经网络，捕捉浓度时序数据的时空依赖关系，实现了复杂结构和风向条件下天然气站场泄漏源的位置和强度的精准估计。

关键词

信息熵；传感器优化配置；源项估计；CEEMDAN-BiTCN-BiGRU 模型

Abstract

When the harmful gas is accidentally released, accurate and efficient source term estimation method is very important to ensure the safe and stable operation of the natural gas station. As the basis of Source term estimate (STE), reasonable sensor layout directly affects the accuracy of STE method. Most of the existing sensor layout methods are only for a specific job and need to know the leak source in advance, which is impractical in STE work. In addition, the existing STE method has poor real-time performance, which is difficult to deal with dynamic scenes. In this paper, an optimal sensor configuration method and STE deep learning model for gas station leakage are proposed, which can be used to achieve fast and accurate estimation of leak point strength and location under complex structure and wind direction. The model introduces information entropy theory, establishes an objective function under multi-objective conditions to optimize the sensor configuration, and introduces the wind direction frequency as the weight coefficient into the objective function. The genetic particle swarm optimization algorithm (GA-PSO) is used to achieve the optimal configuration under complex wind direction conditions. On this basis, a natural gas leakage and diffusion experiment platform and CFD model were built, and a bidirectional deep neural network of BiTCN-BiGUR was constructed to capture the spatio-temporal dependence of concentration time series data, thus achieving accurate estimation of the location and intensity of leakage sources in natural gas stations and yards under complex structure and wind direction conditions.

Keywords

Information entropy; Sensor optimization configuration; Source term estimation; CEEMDAN-BiTCN-BiGRU model

Author: 徐, 后佳 (中国石油大学（北京）)

Co-author: Mr 李, 云涛 (中国石油大学（北京）)

Presenter: 徐, 后佳 (中国石油大学（北京）)

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