Anomaly Detection in Hydrogen Distribution Networks

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Abstract. Hydrogen is one of the best solutions to replace fossil fuels, because the fuel cells has very **high energy density**. The infrastructure is particularly **sensitive to leaks** due to the high volatility of hydrogen gas, the embrittlement and aging of pipelines, and the extensive network of joints and valves. This issue is particularly **critical in distribution systems**, where high-pressure hydrogen leaks can pose significant safety risks. Currently, leakage identification rely on fixed, widely spaced pressure sensors. My main goal is to **explore the possibilities** using **these pressure sensors data for fault detection**.

INTRODUCTION [1] [2]

The use of hydrogen as an energy carrier is important and beneficial for several reasons. When hydrogen is **used as a fuel**, it only produces water as a byproduct, making it an environmentally friendly **alternative to fossil fuels**. Hydrogen can be produced from renewable sources, such as water electrolysis using solar or wind power, ensuring long-term sustainability. It plays a crucial role in reducing carbon emissions in sectors that are difficult to electrify, such as heavy industry and aviation. During the use of hydrogen, **the transportation process is the most critical**, because it is transited by pipelines. The main challenge is **the leakage inside the pipeline**. Because of explosiveness and flammability of hydrogen even a small leak can result dangerous situations. Using pressure sensor data for fault detection in hydrogen transportation networks can be a possible solution for this problem and it can involve various techniques such as Pressure Drop Analysis, Pressure Wave Propagation, Machine Learning & AI-Based Anomaly Detection and Real-Time Pressure Gradient Monitoring.

LITERATURE REVIEW [1]

There are several studies to on this topic and in my opinion the most interesting is a **new hydrogen sensor fault diagnosis method** based on transfer learning. It presents a new method for fault diagnosis of hydrogen sensors using **transfer learning combined with a neural network** architecture. The Developed method is a fault diagnostics method that uses a Convolutional Neural Network **(CNN) as a basis**. CNN is an AI and machine learning model used primarily for image processing and visual data processing tasks. First, the LeNet-5 deep neural network model was **trained on** a large gas sensor fault signal dataset collected under **normal environmental conditions**, so that the system can learn different fault characteristics. The trained model was then **adapted to complex environmental conditions** with limited fault signal data using transfer learning. This allowed the model to use its previously acquired knowledge to provide accurate fault diagnosis in environments,

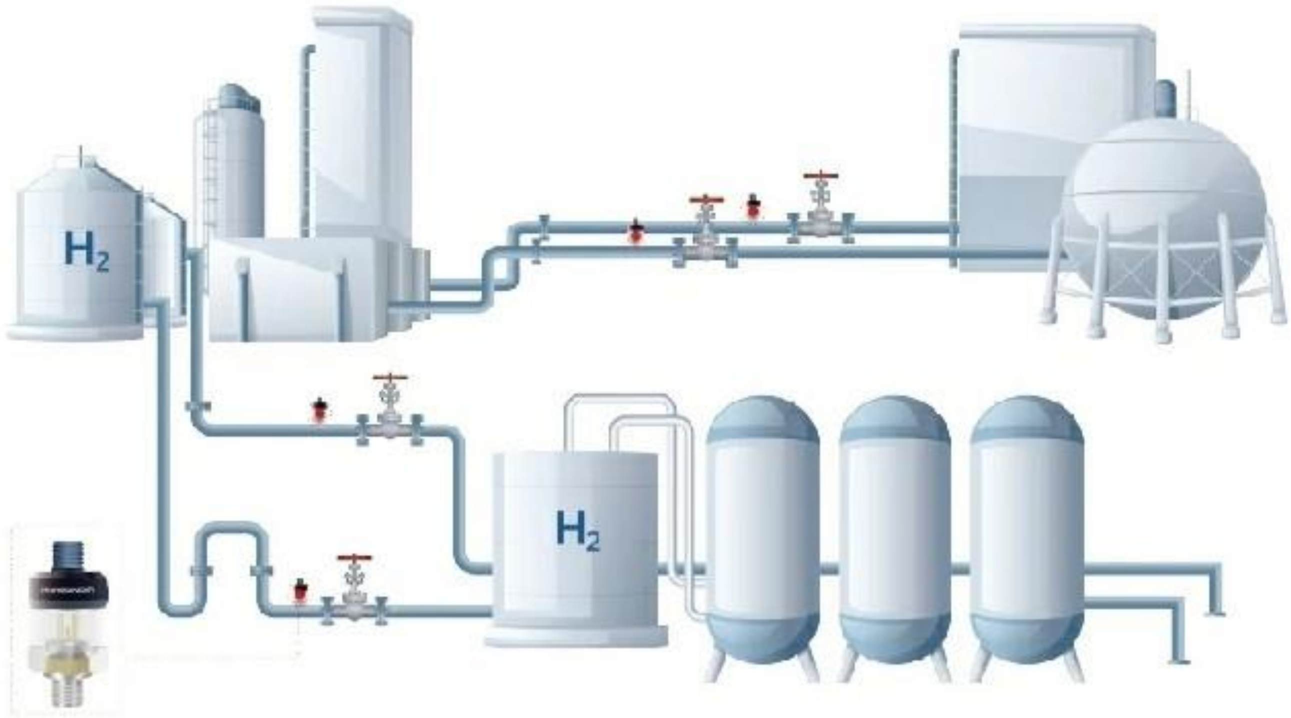

Fig. 1. Hydrogen Pipeline Pressure Measurement System [3]

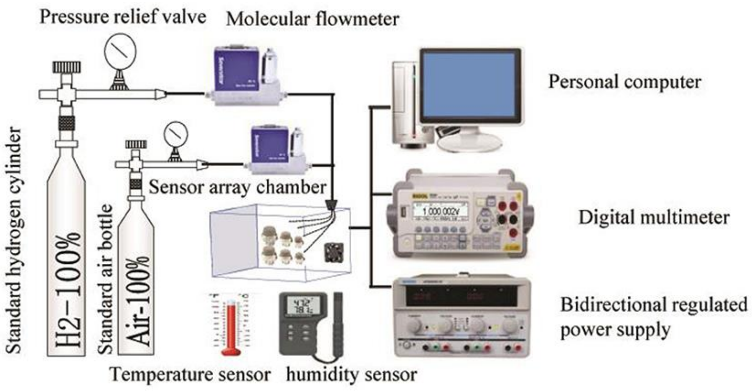

Fig. 2. A system diagram of hydrogen sensor arrays [1]

where **less data is available**. This study shows a huge advance in the failure diagnostics of hydrogen sensors, as it offers a method that can identify sensor failures **even under data-limited conditions**. This is important in industrial applications where sensor reliability is critical for safety.

RESEARCH METHODOLOGY

I am working on the development of a Machine Learning & AI-Based Anomaly Detection system that can **detect faults in pipelines** using pressure sensing systems. The processed source provides a good basis for this, as **ML** is excellent for this purpose and **can provide accurate results** compared to other models that can be used for this purpose.

PRELIMINARY CONSIDERATIONS

Hydrogen is very important and useful, but we need to **solve the challenges** in **the transportation process**. There are limitations in hydrogen leak detection, so there is huge potential of machine learning and AI in this field.

HUMAN CENTERED ASPECTS

The human centered aspects of the problem is **safety**, because explosion can cause harm to people, and **security**, because we don't want to be hacked.

CONCLUSIONS

This study highlights the importance of hydrogen as a sustainable energy source and the challenges of safe transportation, particularly leakage risks in high-pressure pipelines. **Current detection methods** using fixed pressure sensors **are insufficient**, making AI and machine learning-based anomaly detection a promising solution. By leveraging pressure sensor data, the **AI-Based Anomaly Detection can enhance safety**. A key reference is a transfer learning-based fault diagnosis method using LeNet-5, demonstrating AI's effectiveness even with limited data. My goal is to **develop a Machine Learning and AI-based Anomaly Detection System** designed to identify faults, enhancing safety and sustainability in support of a cleaner energy future.

References.

[1] Yongyi Sun, Shuxia Liu, Tingting Zhao, Zhihui Zou, Bin Shen, Ying Yu, Shuang Zhang, Hongquan Zhang: *A New Hydrogen Sensor Fault Diagnosis Method Based on Transfer Learning With LeNet-5,* 2021

[2] Yongyi Sun, Hongquan Zhang, Tingting Zhao, Zhihui Zou, Bin Shen, Lixin Yang: *A New Convolutional Neural Network With Random Forest Method for Hydrogen Sensor Fault Diagnosis,* 2020

[3] MICRO SENSOR CO., LTD: *Hydrogen Pipeline Pressure Measurement*, 2025

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