Continuous monitoring system for the safe storage and use of hydrogen in hydrogenerators

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1 Introduction

Transport is one of the main contributors to climate change. Emitting 32% of CO2 emissions in the European Union (EU) [1]. In this context, a key technological issue revolves around the hydropower infrastructure (HRS) needed for the energy transition.

It is precisely during the storage stage that hydrogen presents the greatest challenges, the most notable being its tendency to explode when mixed with oxygen in a sudden manner: as in a storage tank or valve rupture that causes a sudden release of hydrogen at high pressure.

Current techniques or systems for leak identification include electromechanical impedance, hydrogen sensitive sensors, fiber optics, acoustic cameras or acoustic sensors. Unfortunately, these systems are not able to effectively and inexpensively identify leaks in real time and on a continuous basis. In this context, the need is identified to develop a system capable of detecting leaks quickly and effectively, with the ability to intervene before serious accidents occur.

Therefore, the objective is to develop a novel integral system for detection and management of gas leaks in HRS, capable of: I) performing real-time and continuous leak detection; II) obtaining the location and size of the leak in the main components of the HRS; and III) providing a real-time risk management and analysis system.

2 Methods

To achieve success in the development of this innovative hydrogenator management system, the system will consist of the following subsystems.

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2.1 Data acquisition subsystem

It will consist of ultrasonic microphones distributed throughout the HRS, which will be connected to a single data acquisition system (DAQ) [2]. The system also requires knowledge of the temperature and pressure of the tanks, so these variables will be monitored through the use of thermocouples and pressure sensors.

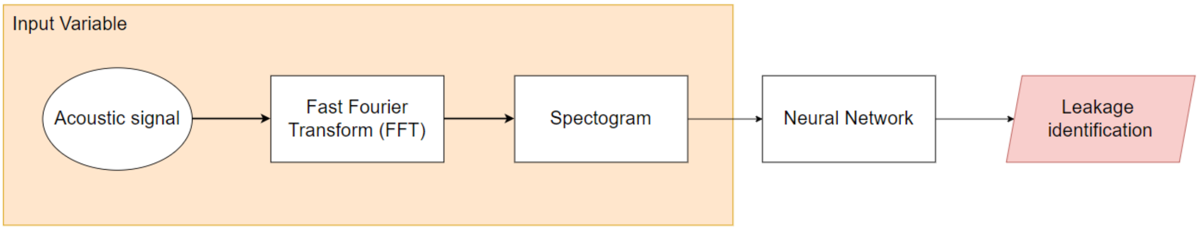

Figure 1. Data acquisition flowchart and Neural Network operation.

The neural network will be based on the use of spectrograms, which are a three-dimensional representation of the sound intensity (amplitude) of a time-varying signal at different frequencies [3].

2.2 Data processing subsystem

Composed of the two-dimensional triangulation algorithm to accurately locate the position of the leak; and a Neural Network in charge of first level leak detection, which will be trained from the Digital Twin.

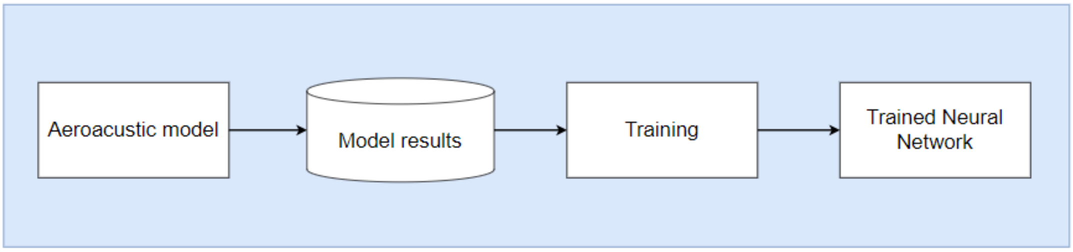

Figure 2. Neural Network training flowchart.

2.3 Digital Twin

It is defined as a comprehensive physical and functional description of the system. In the context of the present proposal, it can be defined as the replication of tanks and piping arranged in the HRS (geometry, state of conservation and other relevant characteristics) [4].

The Digital Twin is fed by the data coming from the instruments and sensors installed in the components such as flow meters, temperature and pressure registers, etc. allowing it to be constantly adjusted and calibrated.

In this way the Digital Twin will allow to replicate the leaks detected at the first level by the acoustic sensors and the Neural Network, generating scenarios similar to reality with which to verify the leak.

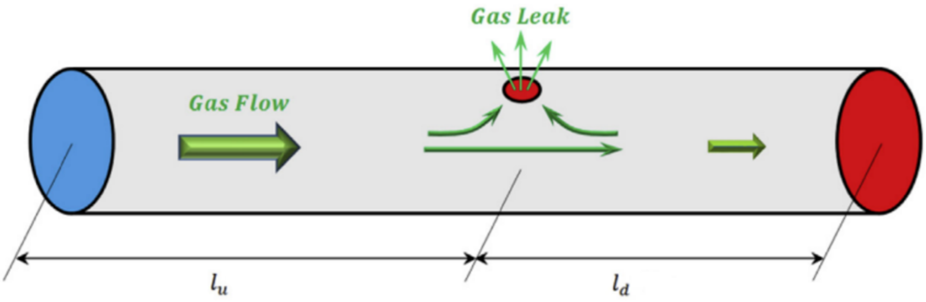

Figure 3. Schematic of the physical model implemented for the Digital Twin of hydrogen distribution pipelines.

In this way, the Digital Twin will make it possible to replicate the leaks detected at the first level by the acoustic sensors and the Neural Network, generating scenarios similar to reality with which to verify the leak, thus reducing the number of false positives.

2.4 Digital Platform

Which will allow access to the information obtained by the system in real time and in a clear, precise an easily understandable manner. The results can be monitored from the platform. The platform will also be responsible for risk management.

3 Results

Applying the proposed methodology of the different subsystems, the solution of the continuous monitoring system of hydrogen use is achieved.

The solution is based on two independent levels of leak detection in order to reduce the number of false positives. The first level is based on the use of acoustic sensors for continuous monitoring of storage tanks and pipelines present in the hydrogenerators.

In the second level, the detected leak is automatically entered into a Digital Twin of the components that make up the hydrogenerator. The simulation is performed in order to verify the temperature and pressure, as well as the flow in the pipeline corresponds to the one recorded in-situ.

Finally, the solution provides an automatic management system and risk analysis of the hydrogen plant based on the previously obtained results.

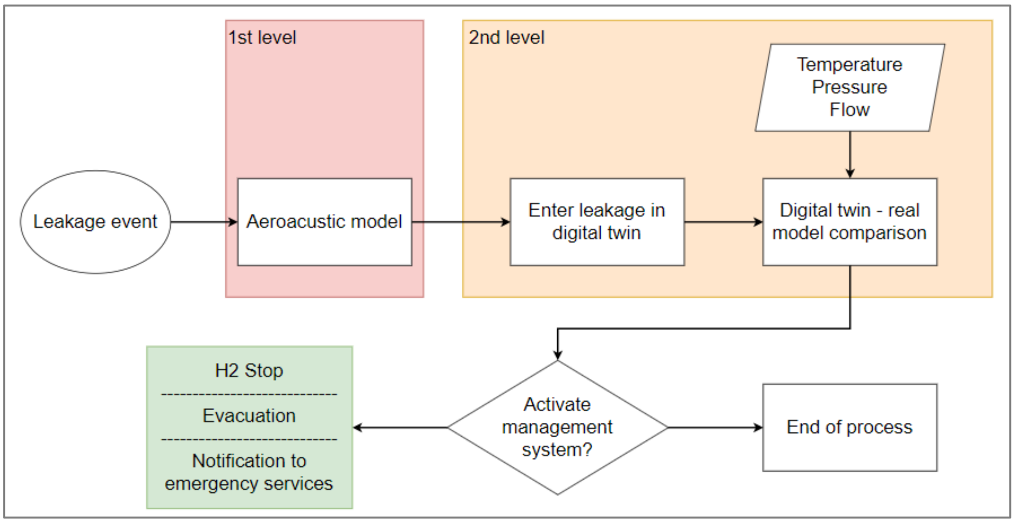

Figure 4. System process flow diagram.

Analyzed the current techniques and unlike others, this new system will allow continuous and real time monitoring of pipes and tanks present in the HRS.

The completed challenges will consist of:

I) Development of a low cost and high sensitivity gas leak detection sensor from the use of an ultrasonic microphone array (MEMS).

II) Development of a Digital Twin (with capability to simulate leaks) integral to the hydrogen storage tanks and distribution piping commonly present at HRSs.

III) Development of a Neural Network for leak identification, capable of distinguishing acoustic waves from leaks by frequency analysis.

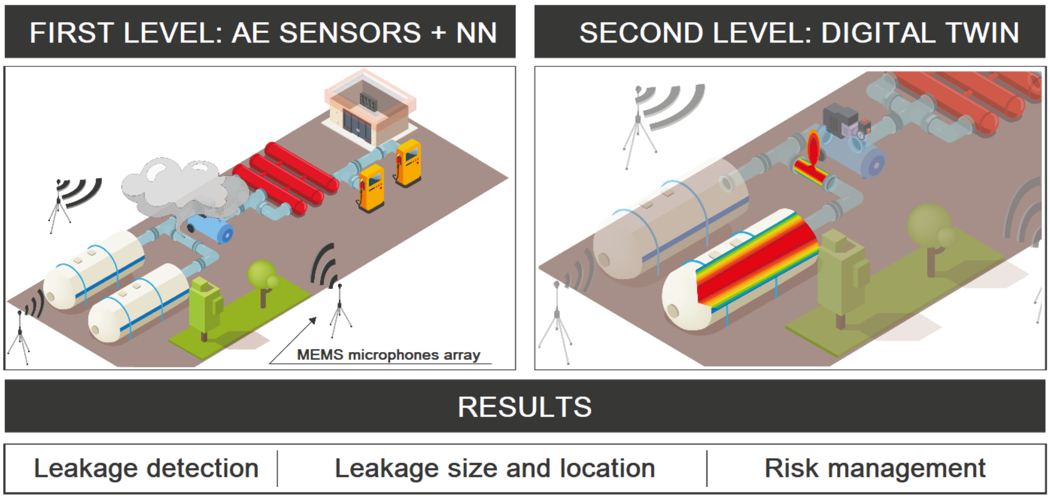

Figure 5. Solution schematic.

4 Conclusions

Once the project has been completed and a degree of technological maturity has been reached, a series of challenges should be overcome in order to reach the future version of the system. These would be the following:

I) Ensure access by seeking strategic partners for the future commercialization of the system, essentially the service provider and/or distributor of the system.
II) Optimization of the system installation process with the objective of reducing the time required for it since the installation requires the interruption of the normal operation process of the HRS.
III) Establish demonstrators with a double objective: 1) to demonstrate the operation and use of the system to potential customers; and 2) to demonstrate the applicability of the system in other relevant operational environments with different casuistry.

References

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