Advancing

THE GLOBAL HYDROGEN PIPELINE NETWORK

Garry Hanmer, Atmos International, UK, explores some of the challenges facing hydrogen transport through pipelines, and how to implement solutions for safe and reliable operations.

As the world accelerates efforts to decarbonise, hydrogen is emerging as a critical energy carrier, enabling the large scale transport of renewable energy. From Europe, North America, Asia-Pacific, and beyond, hydrogen pipelines are becoming an essential component of the energy transition.

While European developments, such as Belgium's pipeline delays, the UK-Germany collaboration, and Greece's tender for a hydrogen pipeline to Bulgaria, have received significant attention, the technical and regulatory challenges they face are not confined to Europe. Pipeline operators around the world must address these challenges to ensure the safe, efficient, and sustainable transport of hydrogen.

There are many technical and regulatory hurdles to overcome to ensure that hydrogen pipelines meet the highest standards of safety and performance. This article will explore some of the solutions that Atmos International provides to support this transition, drawing on the company's experience in pipeline simulation and leak detection.

Europe as a case study: regulatory and technical challenges

Regulatory complexity: Belgium's hydrogen pipeline delay

In Belgium, the flagship hydrogen pipeline project has encountered a year-long delay due to complex permitting and stakeholder processes.[1] This highlights a universal challenge: regulatory frameworks for hydrogen infrastructure are still evolving. Operators worldwide face similar complexities that demand technical readiness and a deep understanding of local regulations.

Digital simulation and monitoring solutions can provide operators with data-driven insights. These solutions help operators comply with diverse regulatory frameworks and mitigate risks, whether in Europe, North America, or Asia-Pacific.

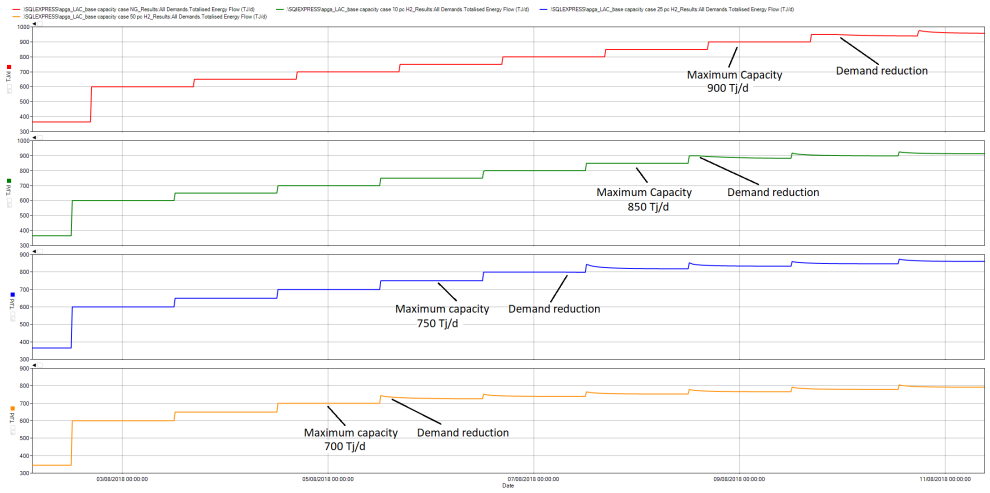

Figure 1. Hydrogen blend maximum capacity calculated by Atmos Simulation (SIM) Suite (red 0%, green 10%, blue 25%, and orange 50%) in an example pipeline network.

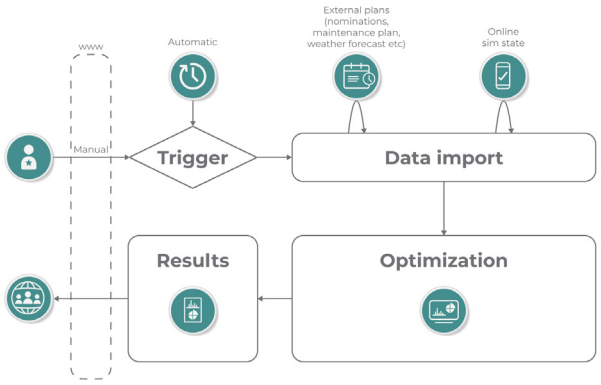

Figure 2. A visual workflow of the process involved in Atmos SIM, providing recommendations for optimised pipeline operation.

Cross-border collaboration: the UK-Germany partnership

The UK and Germany's recent agreement to collaborate on an offshore hydrogen pipeline and to explore a direct pipeline connection exemplifies the complexity of cross-border integration.[2,3] Differences in national regulations, operational standards, and safety requirements necessitate adaptable solutions that enable safe and efficient cross-border transport.

Pipeline simulation software provides a comprehensive solution involving real-time monitoring and simulation capabilities to support safe, efficient, and compliant operations across borders, regardless of local regulations or operational practices.

Regional integration: Greece's tender to Bulgaria

Greece's tender for a hydrogen pipeline to Bulgaria demonstrates the importance of regional integration in developing a resilient hydrogen network.[4] Projects like this are essential to connecting supply and demand centres, promoting market liquidity, and enhancing energy security.

Transient flow modelling and capacity analysis enables operators to design and manage such networks effectively. Through simulation and real-time data integration, it is possible to ensure that operators can plan for fluctuating demand, supply variability, and regulatory requirements.

Technical challenges: a global perspective

Hydrogen embrittlement: a universal risk

Hydrogen embrittlement presents a significant risk to pipelines worldwide. Hydrogen can permeate steel, leading to embrittlement, cracking, and ultimately pipeline failure.[5] On a 160 km pure hydrogen pipeline, Atmos demonstrated the critical role of simulation in mitigating embrittlement risks.

By using the GERG-2004 equation of state and conducting rigorous model tuning, the company achieved simulation results with a deviation of just 0.5% compared to measured flowrates, ensuring high accuracy in predicting pipeline behaviour.[6]

Capacity constraints: impact on network planning

Hydrogen's lower energy density compared to natural gas means that repurposed pipelines can experience significant capacity reductions.

Simulation software can enable operators to model these impacts accurately (see Figure 1), providing the data required for investment decisions, operational planning, and stakeholder engagement.

Technical solutions

Digital twin

Atmos' simulation tools can support hydrogen pipelines worldwide. For example, Atmos Simulation (SIM) Suite provides offline and online simulation functionalities that enable operators to plan, analyse, and monitor pipelines across their lifecycle. Offline modules support steady-state and transient analysis, operator training, and capacity studies, while online modules offer real-time monitoring of pressure, flow, and gas quality (see Figure 2).

This versatility ensures that the tool is adaptable to diverse operating environments, from Europe's interconnected grids to emerging hydrogen networks in North America, Asia-Pacific, and beyond.

Gas quality monitoring: ensuring consistent supply

Delivering hydrogen that meets quality standards is critical for all operators. Atmos SIM's gas quality module enables operators to monitor key parameters, including hydrogen concentration, heating value, and CO_2 levels. This supports regulatory

compliance and ensures that end users receive products that meet contractual specifications.

Hydrogen and natural gas blends need to be accurately modelled across the full range, from 0 - 100% hydrogen. Many older simulation packages rely on equations of state such as Peng Robinson or Benedict Webb Rubin, which are based on the critical properties of individual components and do not include interaction coefficients for hydrogen.

Modern cubic equations, such as GERG-2004, are specifically fitted to the behaviour of mixtures, including hydrogen blends, and are a better choice for accurate and reliable gas quality forecasting.[6]

Atmos SIM can model hydrogen blends accurately for both gas transmission and distribution networks. It is an ideal choice for real time calorific value calculations as more hydrogen and biomethane are introduced to gas networks.

Model tuning: aligning digital models with real-world conditions

Atmos' model tuning process aligns simulations with actual pipeline behaviour. By calibrating factors such as pipeline roughness and heat transfer, operators achieve simulations that match operational data, with deviations of just 0.05% compared to measured flowrates. This accuracy is essential for reliable capacity forecasts, risk assessments, and contingency planning.[6]

Conclusion

The global hydrogen economy demands solutions that are technically advanced, operationally reliable, and adaptable to diverse regulatory and environmental conditions. While Europe currently serves as a high-profile testbed for hydrogen pipelines, the lessons learned there apply globally. Challenges such as hydrogen embrittlement, capacity constraints, and regulatory complexity are not confined to any one region.

Atmos is committed to supporting operators worldwide with advanced simulation tools, leak detection systems, and regulatory expertise. By utilising such technology at every stage, from planning to operations, pipeline operators can build and operate hydrogen infrastructure that meets the highest standards of safety, efficiency, and sustainability.

References

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