

Research News

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Secure hydrogen networks for the future

Innovative Numerical Simulation Methods for Resilient Hydrogen Networks

Green hydrogen is a key area of opportunity in the energy transition. However, the use of pipelines to transport this energy source is associated with a degree of risk. Research scientists at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI, are developing a hydraulic simulation tool to assist with the planning of a resilient hydrogen infrastructure designed to safeguard energy supply.

Green hydrogen, produced for example from surplus wind and solar energy, is a fossil-free energy source that offers certain advantages. It can be stored locally and transported to consumers via supply networks. However, storage and transportation are vulnerable to risk: Natural disasters, sabotage or political sanctions can all jeopardize supply. The careful planning of resilient hydrogen infrastructures is therefore essential to safeguard energy supply, especially when it comes to international networks.

Unique concept: Software maps extreme disruptions

Numerical network modeling offers valuable tools for this purpose. Researchers at Fraunhofer EMI are developing a hydraulic simulation tool with a special focus on analyses of dynamic reactions of hydrogen networks with storage systems to disruptions. It facilitates what-if analyses, helps identifying weak points such as critical system components, classifying them by severity of impact and evaluating the resilience of the entire system. The algorithms accurately represent network behavior even under extreme conditions. When a disruption occurs, they deliver precise information not only on which network elements are no longer supplied but also on the chronological progression of the impact, including how long it is likely to take until supply is restored. "Our software is capable of mapping the most far-reaching disruption scenarios, such as a network that has been disconnected from the supply source for 30 hours," says Till Martini, research scientist at Fraunhofer EMI, explaining the unique concept on which the hydraulic simulation tool is based. "This enables us to map the effects of the disruption on the entire network, for example by showing which network elements are no longer operational and the impact this is having on the system status. Simulating the network's dynamic reactions to extreme events is particularly important."

The numerical simulation method is based on a hydraulic simulation algorithm originally developed as part of the EU's SecureGas project to model natural gas networks in operating conditions that deviate from standard operation. "The development of a hydrogen network in

Germany is a key component of the energy transition. A large part of the core network is to be created by converting existing natural gas pipelines for hydrogen," says Martini. "Hydrogen has different physical properties from natural gas. The molecules are smaller, the diffusion rate is higher, and the pressure conditions will also have to be adjusted. However, the transport principles are still comparable." The researchers at Fraunhofer EMI are therefore building on the tool created during the SecureGas project and developing it further for hydrogen applications so that it can map not only static but also dynamic pressure and flow conditions such as pressure drop in the network. Storage capacities have also been integrated into the numerical simulation. The tool enables flexible modeling of storage facilities and accommodates various storage types and forms.

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Rapid predictions of system behavior before, during and after disruptions

The Fraunhofer tool is the first to enable rapid, continuous predictions of system behavior before, during and after major disruptions in hybrid or pure hydrogen networks of varying sizes, ranging from local distribution grids to international transport networks. Besides facilitating analyses of potential supply bottlenecks and assessments of supply stability, the simulation tool can also be used to test mitigation strategies. "Our simulations show that additional hydrogen storage facilities would be able to compensate for supply shortfalls in the event of a disruption," says Martini, referring to one measure that could make the network more resilient. Using representative scenarios, the researchers have shown that as hydrogen is less dense and has a lower calorific value than natural gas, larger storage capacities would be required for compensation measures to be effective. Overall, analyses of reactions to disruptions and forecasts of survival and recovery times can provide valuable insights for network operators and public authorities when planning resilient hydrogen networks. They can also play a supportive role in resilience and risk assessments for future international energy supply systems.



Fig. 1 Resilient infrastructure is critical for stable hydrogen supply. Simulation tools developed at Fraunhofer EMI analyze network reactions to disruptions and help mitigate risks due to extreme events. © ONTRAS GmbH

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